Recovery from stress

The role of perseverative cognition, affect and demanding shift work

Mirjam Radstaak

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The role of perseverative cognition, affect and demanding shift work

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Promotoren

Prof. dr. S. A. E. Geurts
Prof. dr. M. A. J. Kompier

Copromotor

Prof. dr. J. F. Brosschot (Universiteit Leiden)

Manuscriptcommissie

Prof. dr. C. de Weerth (voorzitter)
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Dr. D. A. J. A. Derks (Erasmus Universiteit Rotterdam)

Voor papa

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General introduction

It is not stress that kills us, it is our reaction to it

HANS SELYE

INTRODUCTION

We all know when we feel stressed. We feel stressed when we are late for an important meeting or when we have to defend our dissertation during a public ceremony. Even though we all are familiar with the tense feeling that makes you sweat, tremble and blush, it is difficult to rationally define our feelings, probably because stress has such different meanings at different times to different people. A commonly used definition of stress that captures these different meanings is proposed by psychologist Richard Lazarus (1966). He defined stress as (p. 9): “a condition or feeling experienced when a person perceives that demands exceed the personal and social resources the individual is able to mobilize”. This perceived inability to cope with demands causes feelings of displeasure and high levels of arousal that are two defining characteristics of stress (Kristensen et al., 1998). A more general and biological definition of stress has been given by the ‘father of stress’ Hans Selye, who defined stress as the “nonspecific response of the body to any demand made upon it” (Selye, 1973, p. 692). This automatic physiological response can be understood from an evolutionary perspective in which early humans had to respond rapidly to existing threats or opportunities for survival. Nowadays, stress in the Western society is caused by the demands of modern life such as mortgages, internet disconnection, big piles of work and deadlines approaching.

Many people spend a great deal of time at work and work demands can be considered to be important stressors in modern life. In the last decades there have been dramatic changes in the nature and conditions of work. Economic, social and technical developments increased competition, the need for efficiency, and the need for a high work pace (Lundberg, 2010). In 1990, 47 percent of European employees indicated their work required a high work pace and this percentage increased to 61 percent in 2010 (Hooftman et al., 2011). Not surprisingly, work stress is common among employees. Almost a fifth of European employees indicated that they experienced work stress in 2005 (Parent-Thirion et al., 2007), and 43% of the Dutch employees indicated that their work caused them to feel stressed in 2013 (Van Zwieten et al., 2013).

Work stress can be defined as the harmful response that occurs when the requirements of the job do not match the capabilities, resources, or needs of the worker (Lazarus & Folkman, 1984). These responses can be psychological (e.g., feelings of depression, anxiety, rumination about work issues and job dissatisfaction [Cheung & Tang, 2010; Cropley et al., 2006; Melchior et al., 2007]), behavioral (e.g., substance abuse, absenteeism and poor job performance [Frone, 1999; Lepine et al., 2005; North et al., 1996]) or physiological (e.g., muscular pain, headaches, hypertension and cardiovascular diseases [Ariens et al., 2001; Christensen & Knardahl, 2012; Kivimäki et al., 2006; Markovitz et al., 2004]).

The reactivity hypothesis posits that exaggerated cardiovascular reactivity to a stressor is a risk factor for the development of hypertension and heart diseases (Krantz & Manuck, 1974; Manuck, 1994). However, the notion that the most cardiac reactive individuals also experience the greatest stress has been challenged because reactivity can also be adaptive, reflecting behavioural flexibility, energy mobilization and effective coping (Dienstbier, 1989). The reactivity hypothesis has also been challenged because it does not take into account whether there is a decrease in cardiovascular activity after a stressful experience, in other words, the degree of cardiovascular recovery (Brosschot & Thayer, 1998; Linden et al., 1997; Schwartz et al., 2003).

Research has yielded evidence that poor cardiovascular recovery is related to ill health (Hocking Schuler & O'Brien, 1997) and even cardiovascular death (Kivimäki et al., 2006). Moreover, cardiovascular recovery seems to be a better predictor of long-term increases in blood pressure than mere reactivity to stressors (Borghi et al., 1986; Steptoe & Marmot, 2005; Stewart et al., 2006). Cardiovascular recovery from acute laboratory stress exposure even predicts cardiovascular health years later. Delayed heart rate recovery after a mental arithmetic task was associated with more preclinical atherosclerosis two years later (Heponiemi et al., 2007), which is a risk factor for cardiovascular diseases (Bots et al., 1997).

A theory that illustrates the crucial role of cardiovascular recovery for health is Effort-Recovery theory (E-R theory: Meijman & Mulder, 1998). Its core assumption is that work is unavoidably associated with effort. This effort is mobilized by the sympathetic-adrenal-medullary (SAM) system that releases the hormones adrenaline and noradrenaline and activates the body for immediate action. For instance, heart rate and blood pressure increase to provide the body with extra oxygen and energy. Under stressful circumstances, the hypothalamic-pituitary-adrenal (HPA) system releases the 'stress hormone' cortisol in order to mobilize supplementary energy needed to deal with the stressful situation (Clow, 2001). According to the E-R theory, this sympathetic activation is functional and not detrimental for health as long as the sympathetic activation returns to pre-stressor levels during after-work hours. In other words, recovery should be completed before the next work day starts. When recovery is incomplete and sympathetic activation has no longer returned to and stabilized at pre-stressor levels, the total load on the individual exceeds homeostatic capacity. This disturbed homeostatic balance has also been referred to as 'allostatic load' (McEwen, 1998) and includes a disturbed sympathetic-parasympathetic balance. This disturbed balance is an important factor in the development of later hypertension and cardiovascular diseases (Brosschot & Thayer, 1998; Thayer et al., 2010).

Incomplete recovery from stress is not only associated with ill health but also with poor psychological well-being. Repeated insufficient recovery invokes cumulated fatigue which increases the likelihood for developing burnout or depression (Demerouti et al., 2004; Garst et al., 2000). Geurts and Sonnentag (2006) define recovery from stress as "a process of psychophysiological unwinding after effort expenditure" (p. 485). They argue that incomplete recovery could manifest itself in subjective reports of incomplete recovery, such as mood and fatigue complaints, but also physiologically, that is, in delayed cardiovascular recovery (Geurts & Sonnentag, 2006; Sonnentag & Geurts, 2009). Therefore, both physiological and psychological recovery should be examined to fully understand the process of recovery from stress. However, relatively few studies have examined the mechanisms associated with psychophysiological recovery (Sonnentag & Fritz, 2007) and there is scant knowledge of the factors that influence recovery.

This thesis will focus on the conditions that impede or facilitate psychophysiological recovery from stress. Specifically, the role of perseverative cognition, negative and positive affect, and demanding shift work will be examined.

Perseverative cognition

People have the tendency to ruminate and worry about stressful events. We ruminate about things we should or should not have said during an important meeting and we worry about upcoming presentations and tight deadlines. These repetitive, uncontrollable and negative thoughts about psychosocial stressors have also been referred to as perseverative cognition (Brosschot et al., 2006). The perseverative cognition hypothesis states that perseverative cognition keeps the stressor 'alive' and prolongs or reactivates the physiological arousal associated with the initial stress reaction and thereby impedes cardiovascular recovery (Brosschot et al., 2006).

Both field and experimental studies have examined the stress prolonging role of perseverative cognition. In a field study among high school teachers, worries and stressful events were associated with simultaneous increases in heart rate and decreases heart rate variability, both indicators of physiological stress. Interestingly, these effects were most pronounced for work-related worries compared to other worry characteristics such as worry about the future or the inability to stop worrying (Pieper et al., 2007). Results from experimental studies also suggest that slow cardiovascular recovery after stress exposure is due to spontaneous rumination about the stressor (Gerin et al., 2006; Glynn et al., 2002; Neumann et al., 2004). After a stressful task, blood pressure recovery was speeded up among participants who were distracted by an engaging but not stressful task. Because rumination was not measured in this study, the authors could only assume that rumination about the stressful event accounted for the slower recovery among participants who were not distracted (Glynn et al., 2002). Later studies did measure stressor-related thoughts and these studies revealed that participants who were distracted after an anger recall task, reported less angry thoughts and showed faster heart rate recovery and blood pressure recovery as compared to participants who were not distracted and sat quietly (Gerin et al., 2006; Neumann et al., 2004).

Perseverative cognition is not only associated with slow cardiovascular recovery from stress, it also impairs the most important recovery opportunity, that is, sleep. Ruminating or worrying about stressors when trying to wind down creates arousal or prolongs the arousal associated with the initial stressor and thereby interferes with sleep. There is conclusive evidence that rumination and worries at bedtime are key factors behind sleeping problems (Harvey et al., 2005). For instance, the apprehension of a difficult workday is associated with decreased amount of slow wave sleep and subjective poor sleep quality (Kecklund & Åkerstedt, 2004). Many studies that examined the association between work-related worries or rumination and poor sleep quality used subjective measures of sleep disturbances (e.g. Åkerstedt et al., 2002; Cropley et al., 2006; Berset et al., 2010; Kompier et al., 2012). There are only few studies that used objective measures of sleep quality (e.g. Pereira et al., 2012). However, people find it difficult to estimate their sleep quality and this difficulty is the main reason why objective and subjective measures of sleep quality do not always correlate (Baker et al., 1999). This suggests that it is important to include both subjective and objective measures of sleep quality when examining the associations between perseverative cognition and sleep.

Affect

The way we feel influences how fast we recover after exposure to a stressful experience. A bad day at work and unfavorable off-job activities make us feel less recovered and more fatigued before bedtime (Sonnentag & Zijlstra, 2006), whereas a good day at work and enjoyable off-job activities make us feel more recovered and happy before bedtime (Van Hooff et al., 2011). The way we feel, further referred to as affect, influences cardiovascular recovery as well.

Negative affect. Results from field studies have shown that negative affect, a feeling of distress, is associated with slower cardiovascular recovery (Brosschot & Thayer, 2003; Kamarck et al., 1998; Pieper et al., 2007; 2010). For instance, in a study among healthy subjects, emotional arousal and physical activity predicted heart rate reactivity, while prolonged activation of heart rate five minutes later was solely predicted by negative affect (Brosschot & Thayer, 2003).

To our knowledge, no experimental study examined the association between the actual experience of negative affect and cardiovascular recovery. Previous experimental studies mostly focused on personality traits such as neuroticism (Hutchinson & Ruiz, 2011) or hostility (Neumann et al., 2004). Field studies that examined the association between the actual experience of negative affect and cardiovascular recovery cannot exclude the possibility that negative affect elicited higher levels of physical activity that in turn slowed down cardiovascular recovery from stress. The field studies that controlled for physical activity only controlled for high levels of physical activity (Pieper et al., 2007; 2010).

Positive affect. The ‘undoing hypothesis of positive emotions’ states that positive affect speeds up cardiovascular recovery from stress. It posits that the adaptive value of positive emotions is to restore the internal equilibrium that is disrupted by the physiological activation caused by negative emotions (Fredrickson & Levenson, 1998). Studies examining the association between positive affect and cardiovascular recovery from stress showed inconclusive results: positive affect has been associated with delayed cardiovascular recovery (Papousek et al., 2010) as well as with faster cardiovascular recovery (Bostock et al., 2011; Fredrickson et al, 2000).

A possible explanation for these contradictory results could be the different levels of arousal that the positive emotions elicited. The circumplex model of affect proposes that all affective states arise from two fundamental dimensions: (1) valence: positive or negative, and (2) arousal: high or low (Russell, 1980). For instance, happiness is an affective state with a positive valence and high arousal whereas relaxation is an affective state with a positive valence and low arousal (Russell, 1980). Because people experience negative affect and high levels of arousal after a stressful event (Kristensen et al., 1998), it is likely that positive affective states that induce low levels of arousal are more effective in facilitating cardiovascular recovery than positive affective states that induce high levels of arousal. To our knowledge, no previous studies examined whether affective states that elicit low or high levels of arousal have different effects on cardiovascular recovery from stress.

Demanding shift work

In modern society, more and more people work during abnormal working hours and shift work has become more common (Geurts et al., 2014). Shift work often encompasses work outside the conventional daytime and thereby covers evening and night work. This puts an extra demand on the recovery process because it disrupts the natural circadian rhythm. Night work requires people to be active at times when they would normally be sleeping and vice versa. It is rare that people achieve a level of adjustment to nocturnal activities by alterations in the timing of circadian rhythms that allow them to remain fully alert during the night, and to sleep as well during the day as normally at night (Folkard, 2008). As a consequence, many shift workers suffer from insufficient and suboptimal sleep which impairs recovery between shifts (Geurts et al., 2014). This lack of recovery might be one of the reasons for the negative health consequences of shift work such as chronic fatigue, depression, gastrointestinal disorders, and cardiovascular disease (Costa, 1996; Vogel et al., 2012).

Various shift work characteristics such as long work hours and high cognitive and emotional demands could magnify the adverse effects of shift work. Long work hours imply a prolongation of work-related effort. This requires an incessant demand on the psychophysiological resources needed to do the job, putting an even higher demand on the recovery process. In addition, long work hours decrease the recovery time left for off-job recovery (Geurts et al., 2014). Long work hours could also interfere with the demands and responsibilities of one's private life. It may create new stressors, such as time-based conflicts which further induce stress and hamper the recovery process (Geurts & Demerouti, 2003). Shift work that is cognitively and emotionally demanding is more likely to deplete psychophysiological resources (Demerouti et al., 2001), which increases the need for recovery. Surprisingly few studies have examined the characteristics of shift work as a modifying factor in the association between shift work and recovery from stress.

AIM OF THIS THESIS

The aim of this thesis is to arrive at a better understanding of the process of recovery from stress by using (i) longitudinal designs, and (ii) subjective and objective recovery measures, (iii) in both experimental and applied settings. The research questions addressed in this thesis are:

1) How does perseverative cognition influence (a) physiological recovery from stress and (b) sleep quality?

2) How does the experience of negative and positive affect influence physiological recovery from stress?
3) How does recovery from stress unfold during and after a period of demanding shift work?

Table 1.1 Overview of the research questions and chapters

Research Question		Chapter 2	Chapter 3	Chapter 4	Chapter 5
1a	How does perseverative cognition influence physiological recovery from stress?	X			
1b	How does perseverative cognition influence sleep quality?			X	
2	How does the experience of negative and positive affect influence physiological recovery from stress?	X	X		
3	How does recovery from stress unfold during and after a period of demanding shift work?				X

OUTLINE

The following outline provides an overview of the specific research questions that will be addressed in each chapter. For an overview of the research questions and chapters see Table 1.1.

Chapter 2 presents the empirical results addressing Research Questions 1a and 2. In an experimental study among undergraduates, stress was elicited by exposing participants to a mental arithmetic task with emotional harassment. After stress exposure, affective levels were manipulated via movie scenes with either a negative, neutral or positive valence, whereas affect was not manipulated in the control condition. During the experiment, heart rate and blood pressure were measured continuously. Using this method, we were able to examine the association between negative and positive affect and physiological recovery from stress (*Research Question 2*). Furthermore, perseverative cognition was measured to examine how stressor-related thoughts are associated with physiological recovery from stress (*Research Question 1a*).

Research Question 2 was also addressed in *Chapter 3.* This experimental study among another group of undergraduates examined the role of positive affect in physiological recovery from stress. Participants were exposed to a mental arithmetic task with emotional harassment to induce stress. After stress exposure, participants listened to either self-chosen relaxing music or self-chosen happy music to induce positive affect and either low levels of arousal (relaxing music) or relatively high levels of arousal (happy music), or were assigned to one of two control conditions. In these two control conditions, participants listened to an audiobook or just sat in silence. Blood pressure and heart rate were measured continuously.

Chapter 4 presents the empirical results addressing Research Question 1b. In a field study among Helicopter Emergency Medical Service (HEMS) pilots, daily stressors, perseverative cognition and subjective and objective sleep quality were measured during three consecutive day shifts. The associations between daily stressors, perseverative cognition and objective and subjective sleep quality were examined to answer the question how perseverative cognition is related to the recovery opportunity par excellence, that is, sleep.

Research Question 3 is addressed in *Chapter 5.* The rich dataset of the HEMS pilots was also used to examine how recovery unfolds during demanding shift work (*Research Question 3*). More specifically, job demands were measured during a series of day and night shifts, whereas levels of well-being were measured before, during and after a series of three consecutive day and night shifts. This method was used to examine how job demands and recovery unfold during a series of day and night shifts influence the recovery process.

The final *Chapter 6* summarizes the main findings of the research and addresses the theoretical implications and recommendations for future research. Furthermore, the strengths and limitations of this thesis will be discussed as well as the practical implications.

2

The role of affect and rumination in cardiovascular recovery from stress

ABSTRACT

This study examined the psychological processes that may impede or facilitate cardiovascular recovery. It was hypothesized that cardiovascular recovery would be hampered by negative affect and rumination, and facilitated by positive affect. In an experimental study, stress was elicited by exposing participants (N =110) to a mental arithmetic task with harassment. After the stress task, affective levels were manipulated via a movie scene with negative, neutral, or positive emotional valence, or without an affect manipulation (control condition). During the entire experiment, heart rate and systolic and diastolic blood pressure levels were measured continuously. Results indicated that blood pressure recovery was hampered by the negative affect manipulation and by rumination. However, the positive affect manipulation did not facilitate blood pressure recovery. No effects were found on heart rate recovery. In sum, the findings emphasize the importance of negative affect and rumination in stress recovery.

Based upon:

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INTRODUCTION

It is widely accepted that stress adversely affects individual health. For example, a longitudinal research has demonstrated that exposure to psychosocial risk factors at work is associated with increased physical and psychological health problems among employees over time (Belkic et al., 2004; Chandola et al., 2008; Kivimäki et al., 2006).

Still, the mechanisms that cause such adverse health effects remain poorly understood. This is possibly due to the predominant focus on physiological 'reactivity' to stressors: physiological responses that occur while the stressor is present. Only limited attention has been paid to physiological 'recovery' after exposure to stressors, that is, physiological responses that prolong or (re)occur when the stressor is no longer present (Linden et al., 1997; Schwartz et al., 2003).

Over the last decade, awareness has risen that recovering from stress is an essential part of a healthy life style. Longitudinal studies have yielded evidence that poor recovery is related to serious health threats such as hypertension (Hocking Schuler & O'Brien, 1997), and even cardiovascular death (Kivimäki et al., 2006). Recovery is also a better predictor of long-term increases in blood pressure than mere reactivity to stressors (Steptoe & Marmot, 2005). Therefore, recovery is seen as a vital link between acute physiological responses to job stressors and employee health (Geurts & Sonnentag, 2006).

The crucial role of incomplete recovery from stress can be understood from the perspective of Effort-Recovery (E-R) theory (Meijman & Mulder, 1998). A core assumption of this theory is that dealing with high demands or stressors requires effort which is mobilized by activation of the Sympathetic-Adrenal-Medullary (SAM) system that, amongst others, regulates cardiovascular activity. E-R theory posits that health is not at risk as long as the physiological activation disappears shortly after the stressor had ended—and thus complete recovery occurs— (Meijman & Mulder, 1998). However, when physiological stress responses prolong and sympathetic activation no longer returns to and stabilizes at a pre-stressor level, the total load on the individual exceeds homeostatic capacity. Such a state is referred to as 'allostatic load' (McEwen, 1998), and includes a disturbed sympathetic–parasympathetic balance that is an important factor in the development of later hypertension and cardiovascular disease (Brosschot & Thayer, 1998; Thayer et al., 2010).

The present study focused on cardiovascular recovery after stress exposure. Specifically, we examined the role of affect and rumination in the recovery process.

The role of affect in stress recovery

Various field diary studies on recovery have provided indirect evidence for the impact of negative and positive affect on the process of stress recovery. For instance, a higher level of negative affect after a work day was associated with higher need for recovery before bedtime (Sonnentag & Zijlstra, 2006). Recently, van Hooff et al. (2011) investigated among university faculty members to what extent subjective parameters of recovery (i.e., fatigue and vigor) at the end of the working day and before bedtime were influenced by positive affect experienced during work and during off-job time. They showed that the experience of pleasure at work and during off-job time had favorable effects on recovery at the end of the working day and before bedtime. Although these studies demonstrate the impact of affective states on subjective recovery, it remains unclear to what extent affective states are related to cardiovascular recovery as well.

Overall, research suggests that negative affect, or feelings of distress, are associated with prolonged stress-related cardiovascular activation, and thus slower cardiovascular recovery (for reviews: Chida & Hamer, 2008; Pieper & Brosschot, 2005). In two real life studies, cardiovascular activity was prolonged between 5 and 45 min after negative emotional episodes, independently of initial response, posture, physical activity, talking, alcohol intake, and other biobehavioral variables (Brosschot & Thayer, 2003; Kamarck et al., 1998). Although these field studies provided evidence for the hampering impact of negative affect on cardiovascular recovery from stress, the role of positive affect in the process of cardiovascular recovery is less clear.

A few laboratory studies with experimentally induced stressors investigated the role of positive affect in stress recovery. A laboratory study in which participants had to answer a difficult statistical question showed that a general positive mood was associated with more complete cardiovascular and subjective post-stress recovery, independent of negative affect. In contrast, a more positive affective state during anticipation of the challenge was related to poorer cardiovascular recovery (Papousek et al., 2010). Another laboratory study on the role of positive and negative affect in stress recovery took a different approach by manipulating affective states after a stressful task (a 60-s speech preparation task). After this stressful task, participants watched 100-s film clips with different emotional valence. Results revealed that a positive affect manipulation facilitated cardiovascular recovery as opposed to a negative affect manipulation (Fredrickson et al., 2000).

The study by Fredrickson et al. (2000) is the only experimental study examining the role of both positive and negative affect in the process of cardiovascular recovery from stress. However, they examined the anticipation of a stressor and did not examine the experience of a real stressor. After the speech preparation task, all participants were 'by chance' selected to watch a video clip and knew that they did not have to actually deliver their speech. In this way the stressor was ended immediately, which may have influenced the recovery process.

The current laboratory study investigated to what extent affective processes hamper or facilitate cardiovascular recovery from a stressful task. After exposure to a stressful event an affective manipulation took place by showing participants a movie with either a negative, neutral, or positive emotional valence, or without an affect manipulation (the control condition). We hypothesized that cardiovascular recovery after stress exposure is slower during the negative affect manipulation (*Hypothesis 1*), and faster during the positive affect manipulation (*Hypothesis 2*), than during the neutral affect manipulation.

The role of rumination in stress recovery

Rumination may be another process responsible for incomplete cardiovascular recovery after stress exposure. All definitions of rumination share the notion of repetitive, intrusive, and negative cognitions about past stressors. Rumination differs from problem-solving in that the repetitive nature of the thoughts is generally non-constructive, strongly negative affect-laden, and not resulting in action that changes the situation (Gerin et al., 2006). The perseverative cognition hypothesis (Brosschot et al., 2006) states that rumination, worry, and related concepts that share the same mechanism of 'repetitive thought' play an important role in the process of incomplete recovery.

Field studies convincingly demonstrate a stress prolonging role for rumination and worry. Field diary studies among employees have shown that negative work-related thoughts during off-job time are associated with insufficient recovery (Sonnentag & Bayer, 2005), and that work-related worry is associated with simultaneous physiological activation (Pieper et al., 2007). Other field studies have shown that worry can mediate the long-term health effects of minor stressors (Verkuil et al., 2012) and a major stressor ("9/11"; Holman et al., 2008). Thus, these cognitions may extend the stress response and impede cardiovascular recovery by causing a continued mental representation of the stressor.

Experimental results also suggest a hampering role of worry and rumination for cardiovascular recovery. Glynn et al. (2002) held spontaneous rumination about the stressor accountable for slow blood pressure recovery after exposure to an emotional stressor (i.e., anger provocation) as blood pressure recovery was speeded up among participants who were distracted from the stressor. Later experiments indeed yielded some evidence that spontaneous rumination may prolong physiological activation: high trait ruminators who were not distracted had the poorest blood pressure recovery (Gerin et al., 2006). Research also has shown that rumination among low trait ruminators hampered blood pressure recovery: low trait ruminators who were still ruminating 10 min after the termination of the stressor had the poorest blood pressure recovery (Key et al., 2008).

In summary, research suggests that repetitive thinking about past stressful events may impede cardiovascular recovery from stress. Therefore, our third hypothesis states that slower cardiovascular recovery after stress exposure is associated with higher levels of rumination about the stress task (*Hypothesis 3*).

Present research

The present study examined the role of negative affect, positive affect, and rumination in the process of cardiovascular recovery after stress exposure. Participants were exposed to a standard stress task in order to raise blood pressure and heart rate levels and to induce negative affect and rumination. After stress exposure, affect was manipulated by showing participants a movie with a negative, neutral, or positive emotional valence (in addition to a control condition). To examine the hypotheses, we analyzed cardiovascular indicators after stress exposure as a function of the affect manipulation (*Hypotheses 1 and 2*) and of rumination (*Hypothesis 3*).

METHOD

Participants

Participants were 110 undergraduates (14 males, 96 females; *M* age = 21.1 years, *SD* = 3.5 years). Participants were randomly assigned to the four conditions. There was no significant association between gender and condition, $\chi^2(3)=1.22$, $p = .75$. All participants were Caucasian. Individuals with hypertension were excluded from participation. Reliable cardiovascular data was obtained from 103 participants. Participants received course credit or a small monetary compensation (€ 7.50).

Cardiovascular recording

Systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were measured during the entire experiment, using a noninvasive beat-to-beat blood pressure monitor (Finometer®, Finapres Medical Systems BV (FMS), Amsterdam, The Netherlands). The inflatable Finometer blood pressure cuff was placed on the third finger of the nondominant hand. The Finometer computed all cardiovascular variables using Beatscope Easy®. This program integrates and controls for gender, age, body mass and weight in calculating cardiovascular indices. Fifteen participants indicated that they were smokers. Because our data revealed that smoking was not related to baseline and reactivity cardiovascular indices, the cardiovascular indices were not controlled for smoking behavior.

The Finometer has been shown to track intra-arterial readings extremely well, even during sudden changes of blood pressure and heart rate (Parati et al., 1989), making it quite useful for cardiovascular reactivity and recovery testing. With a beat-to-beat technique, summary measures of blood pressure and heart rate are extremely reliable because of the large number of measurements that are averaged (Gerin et al., 1993).

Stress task

The stress task, a mental arithmetic task with harassment, was strongly based on a standard anger provocation task (Brosschot & Thayer, 1998; Glynn et al., 2002). Participants were instructed to count back from 9000 in steps of 17. During counting, the experimenter interrupted the participants three times during the first minute and told them to start over again, (1^{st} interruption), made a disapproving noise (2nd interruption), and told them the task was made easier by counting back from 9000 in steps of 13 (3rd interruption). In the remaining four minutes, participants were told that they counted back to slowly (4th interruption), that they really needed to concentrate (5th interruption) and that the task was ended because they really showed no improvement (6th interruption). The stress task lasted five minutes.

Affect manipulation

For the induction of affect, a movie scene with either a negative emotional valence ('Sophie's Choice'), a neutral emotional valence ('Planet Earth'), or a positive emotional valence ('There's something about Mary') was used.

In a pilot study, 32 other participants watched the movie scenes without previous exposure to the stress task. There were no differences between the three movie scenes in systolic blood pressure (SBP), $F(2, 29) = .97$, $p = .39$, $\eta\rho^2 = .06$, diastolic blood pressure (DBP), $F(2, 29) = 1.41$, $p = .26$, $\eta\rho^2 = .09$, or heart rate (HR), $F(2, 29) = .50$, $p = .62$, $\eta\rho^2 = .03$. There were also no changes in these cardiovascular indicators for each condition compared to baseline. For the negative condition: SBP, $t(9)= -1.52$, $p = .16$, $d = -.49$; DBP, $t(9)= -1.67$, $p = .13$, $d = -.57$; HR, $t(9)= 1.27$, $p = .24$, $d = .41$. For the neutral condition: SBP, $t(10)= -1.63$, $p = .13$, $d = -.61$; DBP, $t(10)= -1.31$, $p = .22$, $d = -.41$; HR, $t(10)= 2.17$, $p = .06$, $d = .70$. For the positive condition: SBP, $t(10)= -1.03$, $p = .33$, $d = -.33$; DBP, $t(10)= -1.18$, $p = .27$, $d = -.32$; HR, $t(10)= 1.35$, $p = .21$, $d = .44$. Thus, the negative affect manipulation was not an additional stressor eliciting cardiovascular responses itself. Effect sizes were small ($d = .2$ to $.5$) or medium ($d = .5$ to $.8$) (Cohen, 1988).

Questionnaire measures

Negative affect. Negative affect was measured with three items: 'At this moment I feel irritated', 'At this moment I feel tense', and 'At this moment I feel angry'. Items were rated on a 10-point Likert scale (1 = *strongly disagree*, 10 = *strongly agree*) and showed good reliability ($\alpha = .82$).

Positive affect. One item was used to measure positive affect: 'At this moment I feel happy'. This item was rated on a 10-point Likert scale (1 = *strongly disagree*, 10 = *strongly agree*).

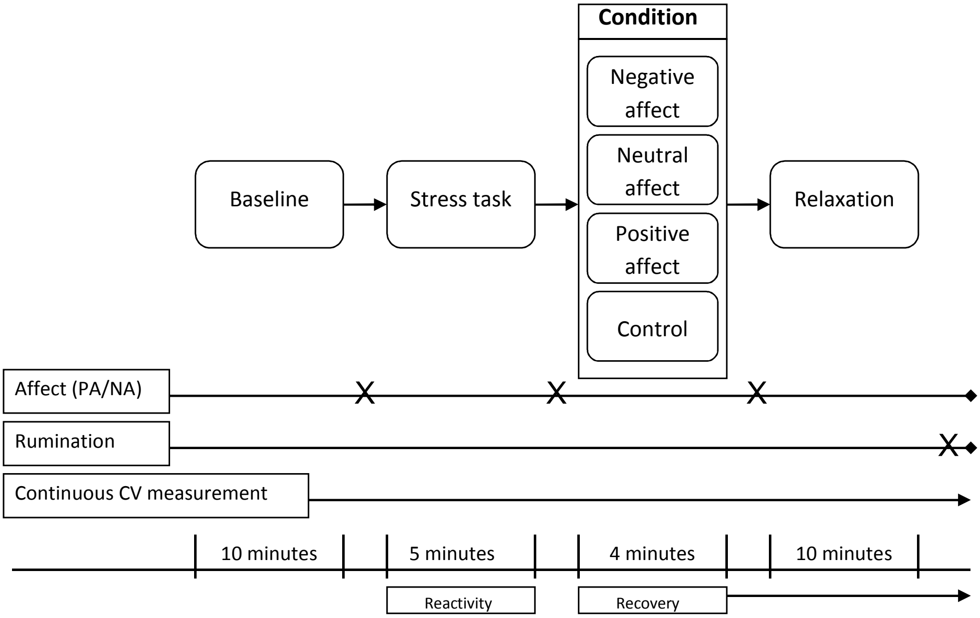
Rumination. Rumination was measured by the item: 'I ruminated about the mental arithmetic task since I finished the task'. For the word 'to ruminate' we used the Dutch word 'piekeren'. This item was rated on a 1–5 point Likert scale (1 = *almost never*, 5 = *very often*).

Procedure

Figure 2.1 shows the schematic overview of the procedure. When participants arrived in the laboratory, they were told that they took part in an experiment 'about movies and bodily processes' and that their blood pressure and heart rate would be monitored. They were instrumented with the finger cuff and instructed to sit quietly and relax. The experimenter left the room and baseline blood pressure and heart rate levels were measured for 10 min. Subsequently, the experimenter returned and gave instructions to complete questionnaires and left the room again. After participants completed the questionnaires, the experimenter returned and started with the five-minute stress task.

After the stress task, participants were randomly assigned to one of four conditions: negative affect, neutral affect, positive affect, or control. Participants watched one of the three affect-inducing movies, or were instructed to just sit back and relax if they were in the control condition. After the instructions, the experimenter left the room. The affect manipulation ended after four min. The experimenter returned and gave instructions to rate current mood. After completing these ratings, participants were instructed to relax for 10 min, during which the experimenter was again not present. After this period the experimenter returned and told that the experiment was almost finished except for a few questions measuring demographic data (age, gender) and rumination about the stress task. When these were completed, the finger cuff was removed and participants were debriefed and thanked for their participation. They received money or course credit for participation.

Figure 2.1 Schematic overview of the procedure.



Note: X = Measurement.

Preliminary statistics

*Stress induction***.** Average BP and HR measures were computed for the baseline period and the stress task period (see Figure 2.1). First, we examined whether the stress task successfully increased blood pressure, heart rate, and negative affect, and decreased positive affect. Paired t-tests were used comparing baseline and stress task levels. Significant differences would verify that the stress task increased cardiovascular indices and negative affect and decreased positive affect.

Affect manipulation. To examine whether the affect manipulations successfully induced different affective states, the reported affective state after each affect manipulation was compared to the reported affective state before the affect manipulation (after the stress task) using paired t-tests. Significant t-values would indicate that affective state changed during the affect manipulation.

To examine whether negative and positive affect recovery were the same between conditions, difference scores (post-affect manipulation minus post-stress task) were calculated. An ANOVA with the differences scores as dependent variables and condition (negative affect condition vs. neutral affect condition vs. positive affect condition vs. control condition) as between-subjects factor was used to examine whether affect recovery differed between conditions.

Cardiovascular recovery. During the affect manipulation period, cardiovascular indices were averaged in parts of 15 s. These parts were used as dependent variables in a multilevel growth curve model (Singer & Willet, 2003). Growth curve modeling was used because it is a flexible and powerful method for the analysis of change over time (Cillessen & Borch, 2006).

Separate models were run for SBP, DBP and HR. First, an unconditional growth model (UGM) was fitted to the blood pressure and heart rate data. This model tests whether blood pressure and heart rate levels show a linear change during the manipulation period of 4 min. This is important because the current research focused on time linear trends for the test of the hypotheses. In order to reduce any variance that may be due to a curvilinear time trend, we added a $Time^2$ trend as a covariate to the UGM model. Third, the interactions between the linear time trend and centered cardiovascular baseline levels and centered cardiovascular reactivity levels (stress task period), were added as covariates to the multilevel model. By this means, differences in cardiovascular recovery cannot be attributed to differences in baseline and reactivity values. The improvements of model fit were examined using χ^2-test. A strong improvement in model fit indicates a strong effect of the predictor on cardiovascular recovery.

Tests of main study hypotheses

Separate analyses were run for SBP, DBP and HR. The first analyses examined whether the negative affective manipulation would hamper (*Hypothesis 1*), and the positive affective manipulation would speed up (*Hypothesis 2*) cardiovascular recovery (SBP, DBP and HR). Therefore, the interaction between the linear time trend and condition was added as a predictor to the basic model. A significant interaction effect would indicate that cardiovascular recovery would differ per condition. The neutral affect condition was used as the reference group to which the other three conditions (negative affect condition, positive affect condition and control condition) were compared.

Next, we examined whether rumination hampered cardiovascular recovery (*Hypothesis 3*). Therefore, the interaction between the linear time trend and rumination, as a centered variable, was added to the basic model. A significant positive interaction effect would indicate that a higher degree of rumination was associated with slower cardiovascular recovery. Separate analyses were run for SBP, DBP and HR.

RESULTS

Preliminary results

Stress induction. The descriptive statistics for all variables are shown in Table 2.1. Table 2.1 (first column) presents the cardiovascular measures (first three rows) for the total sample during the baseline period and the stress task period. Paired t-tests revealed that systolic blood pressure, diastolic blood pressure, and heart rate all increased significantly during the stress task (SBP, $\Delta M = 30.32$, $t(102) = -22.20$, $p < .001$, $d = -2.20$; DBP, $\Delta M = 17.01$, $t(102) = -24.89$, $p < .001$, $d = -2.45$; HR, $\Delta M = 11.66$, $t(102) = -13.45$, $p < .001$, $d = -1.32$). The fourth and fifth rows in Table 2.1 present the affective measures (negative and positive affect) after the baseline period and after the stress period. A paired t-test revealed that the level of negative affect was significantly higher than baseline after the stress task ($\Delta M = 2.37$, $t(109) = -12.96$, p

Table 2.1 Descriptive statistics for cardiovascular measures, affect measures and rumination for the total group and for each of the four conditions.

	Total		Negative affect condition		Neutral affect condition		Positive affect condition		Control condition	
	N	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*M (SD)*
Systolic blood pressure										
Baseline	103	120.66 (14.99)	23	122.35 (19.05)	28	121.41 (15.01)	26	117.93 (14.17)	26	121.08 (11.94)
Stress task	103	150.98 (16.99)	23	149.75 (16.32)	28	150.21 (17.41)	26	146.94 (17.99)	26	156.96 (15.37)
Diastolic blood pressure										
Baseline	103	63.22 (10.00)	23	64.82 (12.66)	28	64.88 (8.01)	26	61.55 (10.91)	26	61.70 (8.22)
Stress task	103	80.23 (9.62)	23	79.03 (10.99)	28	81.85 (9.34)	26	78.25 (9.46)	26	81.54 (8.80)
Heart rate										
Baseline	103	76.86 (10.95)	23	71.59 (8.06)	28	76.89 (13.27)	26	77.93 (10.64)	26	80.44 (9.39)
Stress task	103	88.52 (11.48)	23	82.55 (7.32)	28	87.43 (13.40)	26	89.22 (12.37)	26	94.26 (8.64)
Negative affect (1-10)										
Baseline	110	2.47 (1.21)	26	2.49 (1.21)	29	2.79 (1.26)	27	2.40 (1.11)	28	2.18 (1.25)
After the stress task	110	4.84 (1.88)	26	4.69 (1.69)	29	5.38 (1.83)	27	5.21 (1.79)	28	4.07 (1.98)
After the affect manipulation	110	3.62 (1.78)	26	4.38 (1.77)	29	3.64 (1.78)	27	3.32 (1.67)	28	3.17 (1.74)
Positive affect (1-10)										
Baseline	110	6.45 (1.33)	26	6.55 (1.29)	29	6.48 (1.18)	27	6.52 (1.28)	28	6.14 (1.46)
After the stress task	110	4.76 (2.06)	26	5.31 (2.15)	29	4.52 (1.88)	27	4.74 (1.87)	28	4.54 (2.32)
After the affect manipulation	110	5.38 (1.93)	26	4.27 (1.99)	29	5.48 (1.64)	27	6.48 (1.16)	28	5.25 (2.21)
Rumination (1-5)										
After the relaxation period	110	2.67 (1.26)	26	3.04 (1.31)	29	2.70 (1.23)	27	2.64 (1.19)	28	2.31 (1.27)

< .001, *d* = −1.29). Positive affect was significantly lower than baseline after the stress task (Δ*M* = −1.69, *t*(109) = 9.26, $p < .001$, *d* = .93). Thus, the stress task effectively induced physiological and psychological stress, and the effects were large (*d* > .8) (Cohen, 1988).

Affect manipulation. Table 2.1 (4th and 5th rows) also shows the affective reports directly after the manipulation period (3rd to 6th columns). Paired t-tests revealed that after the negative affect condition (column 3), the level of negative affect remained as high as after the stress task (t(25) = .98, *p* = .34, *d* = .19), while positive affect decreased (*t*(25) = 2.11, $p < .05$, *d* =.42). In the other three conditions (4th, 5th and 6th columns), negative affect was significantly lower after the manipulation period than after the stress task (neutral affect condition: *t*(28) = 6.03, $p < .001$, *d* = 1.12; positive affect condition: *t*(26) = 8.73, $p < .001$, *d* = 1.69); control condition: *t*(27) = 3.27, $p < .01$, *d* = .62). Positive affect was significantly higher after the manipulation period than after the stress task (neutral condition: *t*(28) = −2.61, $p < .05$, *d* = −.49; positive condition: *t*(26)= −6.71, $p < .001$, *d* = −1.48; control: *t*(27) = −2.54, $p < .05$, *d* = −.48)

The decrease in negative affect during the affect manipulation differed significantly between conditions: *F*(3,109) = 7.02, $p < .001$, $\eta\rho^2 = .17$. Post-hoc analyses showed that the decrease in negative affect was significantly smaller in the negative affect condition (Δ*M* = −.31) than in the positive affect condition (Δ*M* = −1.89), and the neutral condition (Δ*M* = −1.74). The decrease in negative affect in the control condition (Δ*M* = −.90) did not differ from any of the other conditions. The change in positive affect also differed significantly among the four conditions; *F*(3, 109) = 10.29, $p < .001$, $\eta\rho^2 = .23$. Post-hoc analyses showed that positive affect further decreased in the negative affect condition (Δ*M* = −1.04), whereas positive affect increased in all other conditions (neutral affect condition: Δ*M* = .96, positive affect condition: Δ*M* =1.74, control condition: Δ*M* = .71). No differences in positive affect changes were found among the positive affect condition, the neutral affect condition, and the control condition. Thus, the negative affect manipulation effectively maintained a high level of negative affect while reducing positive affect. The other three conditions were effective in reducing negative affect and increasing positive affect. Overall, effect sizes were medium to large (Cohen, 1988). These results are graphically presented in Figure 2.2 (negative affect) and Figure 2.3 (positive affect).

Cardiovascular recovery. To examine whether the cardiovascular measures showed a linear decrease during the affect manipulation period, an Unconditional Growth Model was fitted to the blood pressure and heart rate data that consisted of 16 data points. The results showed that both blood pressure decreased during the affect manipulation (SBP: $\gamma10 = -1.89$, $p <.001$; DBP: $\gamma10= -.46$, $p <.001$), and model fit improved significantly (SBP: $\chi^2(3) = 646.32$, $p < .001$; DBP: $\chi^2(3) = 358.37$, $p < .001$). However, we could not observe a linear change in heart rate during the affect manipulation period (HR, $\gamma10 = .01$, *p* =.94), even though model fit improved ($\chi^2(3) = 157.96$, $p < .001$). Post-hoc analyses revealed that heart rate reached baseline levels (*M* =76.86) within 30 seconds of the affect manipulation period (*M* =76.34); *t*(102) = .53, *p* = .60. Therefore, we were not able to test our hypotheses with the heart rate data and these data were not further considered.

Figure 2.2 Levels of *negative* affect (NA) after the stress task and after the affect manipulation.

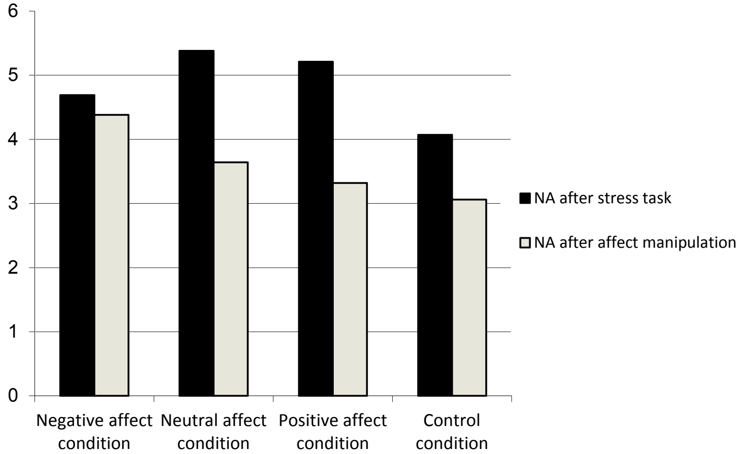
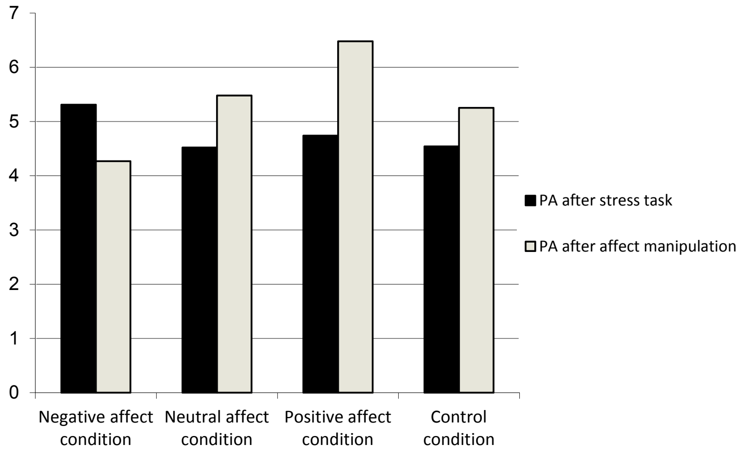


Figure 2.3 Levels of *positive* affect (PA) after the stress task and after the affect manipulation.



Model A in Table 2.2 shows the estimates of the basic model with, among others, the time linear trend ('Time') and the quadratic time trend ('Time^2') as predictors. To simplify the interpretation of the results, the blood pressure estimates (per 15 s) were multiplied by four. This means that Table 2.2 shows estimates of BP recovery per minute. The quadratic time trend significantly improved model fit for both SBP and DBP (SBP: $\chi^2(1) = 222.48$, $p < .001$; DBP: $\chi^2(4) = 230.51$, $p < .001$), indicating that some variance in blood pressure changes during the affect manipulation was captured by a curvilinear trend. When baseline levels and reactivity levels of SBP and DBP were added to the basic model, model fit improved significantly (SBP: $\chi^2(2) = 15.78$ $p < .001$; DBP: $\chi^2(2) = 28.13$, $p < .001$). Apparently, individual differences in BP recovery during the affect manipulation were related to individual differences in baseline and reactivity values. In order to control for these pre-manipulation differences in BP levels, baseline BP and reactivity BP were added to the basic model.

Test of main study hypotheses

Affect in relation to blood pressure recovery (Hypotheses 1 and 2). Table 2.2, Model B, shows the BP differences per condition, as compared to the neutral affect condition. In general, SBP recovery differed among conditions ($F(3, 102) = 2.83$, $p < .05$) and model fit improved, ($\chi^2(3) = 8.12$, $p < .05$) whereas DBP recovery did not differed among conditions ($F(3, 103) = 1.24$, $p = .30$) and model fit did not improve ($\chi^2(3) = 3.58$, $p = .31$). In more detail, SBP recovery was significantly slower in the negative affect condition than in the neutral affect condition: $\gamma14 = 1.34$, $p < .01$. This effect was not significant for DBP: $\gamma14 = .31$, $p = .30$. Thus, Hypothesis 1 was supported for SBP recovery but not for DBP recovery. SBP and DBP recovery in the positive affect condition did not differ from SBP and DBP recovery in the neutral affect condition (SBP, $\gamma15 = .76$, $p = .10$, DBP, $\gamma15 = -.22$, $p = .44$). Hypothesis 2 was not supported. Figure 2.4 shows the SBP recovery in each condition during the 4 min of the affect manipulation period.

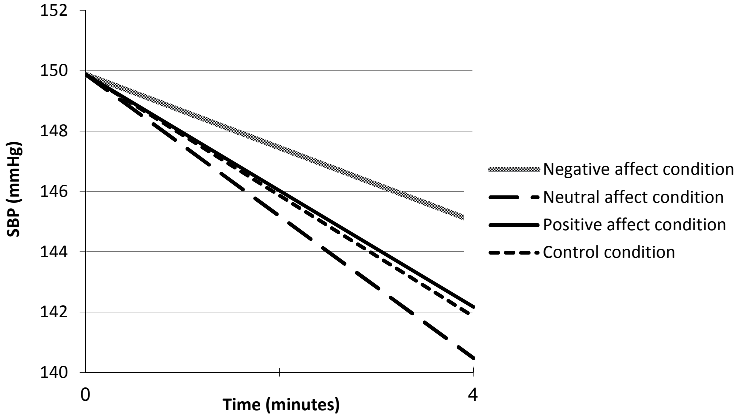
Rumination in relation to cardiovascular recovery (Hypothesis 3). Table 2.2, Model C, shows whether BP recovery during the affect manipulation period was related to levels of rumination. Table 2.2 shows that rumination was significantly and positively related to both SBP and DBP levels during the manipulation period (SBP: $\gamma17 = .27$, $p < .05$; DBP: $\gamma17 = .16$, $p < .05$), and model fit improved (SBP: $\chi^2(1) = 4.26$, $p < .05$; DBP: $\chi^2(1) = 4.06$, $p < .05$). This indicates that higher levels of rumination were associated with slower blood pressure recovery. Thus, Hypothesis 3 was supported.

Table 2.2 Blood pressure recovery during the affect manipulation.

	SBP			DBP		
	Model A	Model B	Model C	Model A	Model B	Model C
Initial status						
Intercept, γ00	149.88 (1.87)***	149.88 (1.87)***	149.88 (1.87)***	75.53 (1.08)***	75.53 (1.08)***	75.53 (1.08)***
Rate of change						
Time, γ10	-6.58 (.67)***	-7.22 (.73)***	-6.58 (.67)***	-3.31 (.37)***	-3.38 (.40)***	-3.31 (.37)***
Time², γ11	2.38 (.29)***	2.38 (.29)***	2.37 (.29)***	1.44 (.16)***	1.44 (.16)***	1.44 (.16)***
Baseline BP, γ12	.05 (.01)**	.05 (.01)**	.05 (.01)**	.06 (.02)***	.07 (.02)***	.07 (.02)***
Reactivity BP, γ13	.05 (.01)***	.05 (.01)***	.05 (.01)***	.05 (.02)**	.04 (.02)*	.05 (.02)**
Neutral affect versus						
Negative affect, γ14		1.34 (.46)**			.31 (.29)	
Positive affect, γ15		.76 (.45)			-.22 (.28)	
Control, γ16		.60 (.46)			.19 (.29)	
Rumination, γ17			.27 (.12)*			.16 (.08)*

Note: * $p < .05$; ** $p < .01$; *** $p < .001$. Model A is the basic model. Model B is the theoretical model with condition as predictor of time linear change. Model C is the theoretical model with rumination as predictor of time linear change.

Figure 2.4 Systolic blood pressure recovery from stress per condition



DISCUSSION

Previous research has shown that incomplete recovery from stress is associated with serious health threats (Hocking Schuler & O'Brien, 1997; Kivimäki et al., 2006; Steptoe & Marmot, 2005). Therefore, it is important to understand the process of stress recovery. The present experimental study examined psychological mechanisms that may underlie physiological recovery from stress. Specifically, we examined to what extent cardiovascular recovery was impeded by negative affect (*Hypothesis 1*), speeded up by positive affect (*Hypothesis 2*), and hampered by rumination (*Hypothesis 3*).

Affect and cardiovascular recovery

Consistent with our expectations, participants showed slower systolic blood pressure recovery after stress exposure when they watched a movie with a negative emotional valence (negative affect condition) than participants who watched a movie with a neutral emotional valence (neutral affect condition). This is in line with earlier research indicating an association between negative affect and prolonged cardiovascular activity, that is, slower cardiovascular recovery (Chida & Hamer, 2008; Pieper & Brosschot, 2005). One could argue that a negative affect manipulation is a stressor in itself, causing cardiovascular activation and, hence, impeding cardiovascular recovery. However, our negative affect manipulation by itself did not induce any cardiovascular activation as shown in our pilot study. Therefore, we conclude that negative affect was responsible for slowing down blood pressure recovery after stress exposure, but not for again elevating blood pressure levels.

Contrary to our expectations, participants who watched a positively valenced movie did not show faster cardiovascular recovery after stress exposure than participants in the neutral affect condition. This could be explained by an ineffective positive affect manipulation because levels of positive affect were not higher in the positive affect condition than in the neutral condition. This finding was somewhat surprising because earlier research using a positive movie scene successfully induced positive affect and facilitated cardiovascular recovery (Fredrickson et al., 2000). It is possible that the content of the movie scene used by Fredrickson et al. (2000) had a stronger positive affective valence than our movie scene. Another possibility is that our stress task was more severe than the one used by Fredrickson et al. (2000), and needed a stronger positive affect manipulation to effectively induce positive affect. Indeed, stress reactivity (blood pressure level during stress task minus baseline blood pressure) was higher in our study (ΔSBP = 30.32 mm Hg, ΔDBP = 17.01 mm Hg) than in Fredrickson et al. (2000) (SBP=14.03 mm Hg, DBP=1.97 mm Hg).

Rumination and cardiovascular recovery

The perseverative cognition hypothesis argues that repetitive thoughts impede stress recovery (Brosschot et al., 2006). The present study supports this assumption; rumination was associated with decreased blood pressure recovery from stress. This is also in line with Pieper et al.'s (2007) finding that teachers who reported higher levels of work-related worry also showed higher levels of cardiovascular activation. Nevertheless, the current study is among the first to show a direct association between rumination and cardiovascular recovery from stress. In earlier experimental research rumination was not measured (Glynn et al., 2002), was not empirically related to cardiovascular recovery (Gerin et al., 2006), or was related to cardiovascular recovery only in a specific subsample (Key et al., 2008).

Limitations and suggestions for future research

The current study had some limitations. First, heart rate was excluded from the analysis because it did not show a linear decrease during the affect manipulation. Heart rate levels already had returned to baseline levels within 30 s after the stress task ended. Earlier research examining psychological mechanism in relation to heart rate recovery also failed to find an effect on heart rate recovery (Gerin et al., 2006; Glynn et al., 2002; Papousek et al., 2010). This raises the question whether heart rate is a suitable measure for the examination of prolonged physiological responses to psychological stressors. Perhaps heart rate variability is a useful alternative. Heart rate variability, as a more specific marker of parasympathetic activity than heart rate, has been associated with a wide range of psychosocial stressors, and seems to play a crucial role in stress recovery (Brosschot & Thayer, 1998; Thayer & Brosschot, 2005; Thayer et al., 2010). In addition, blood pressure variability or another marker of sympathetic nervous activity might be added, to better distinguish between sympathetic and parasympathetic activity of the autonomous nervous system.

Second, we should discuss the differential effect of our affect manipulation on systolic and diastolic blood pressure recovery as only systolic blood pressure recovery was hampered in the negative affect condition. Earlier studies also have shown differential relationships of negative affect constructs with blood pressure recovery. Some studies found only associations with systolic blood pressure recovery (Anderson et al., 2006; Neumann et al., 2004; Vella &

Friedman, 2009). Others found only associations with diastolic blood pressure recovery (Key et al., 2008; Pardine & Napoli, 1983). A closer examination of these studies reveals that hostility, which is suggested to be affected by sympathetic activation (Kreibig, 2010), seems to be more associated with systolic blood pressure recovery (Anderson et al., 2006; Kreibig, 2010; Neumann et al., 2004; Vella & Friedman, 2009). In contrast, concepts related to depressive mood, which is suggested to be affected by both parasympathetic and sympathetic activation (Kreibig, 2010), seems to be associated more strongly with diastolic blood pressure recovery (Key et al., 2008; Kreibig, 2010; Pardine & Napoli, 1983). It could be that our negative affect manipulation induced a negative affective state that may be more closely related to hostility than to sadness, explaining the higher impact on systolic blood pressure recovery. Future research could induce different negative affective states after stress exposure in order to examine differential effects on systolic and diastolic blood pressure recovery.

A third point of discussion is the manipulation of positive affect. The method used in the current study did not induce higher levels of positive affect in the positive affect condition than in the neutral affect condition. Future research would benefit from a stronger positive affect manipulation. This could be achieved in several ways. One is to lengthen the affect manipulation. A movie scene longer than 4 min might increase positive affect more. A longer positive affect manipulation, that is, a potentially longer recovery period, would also give more time to physiologically unwind from the stressor. Research has indeed shown that during an extended recovery period of 10 min, positive affect speeded up blood pressure recovery (Steptoe et al., 2007). Another strategy to enhance positive affect may be to change the content of the positive movie scene. Fredrickson et al. (2000) showed that a movie scene with puppies was effective to induce positive affect. Yet another strategy may be to use another type of positive affect manipulation such as listening to music, which is effective to facilitate cardiovascular recovery (Chafin et al., 2004; Labbé et al., 2007).

A fourth issue concerns the measurement of rumination. Rumination was measured by a single item, which could have been detrimental to the reliability and validity of the measure. However, research has shown that when a construct is very specific, as it is in the present research, a single-item measure is a legitimate alternative to a multiple-item measure (e.g., Robins et al., 2001; Sacket & Larson, 1990; Van Hooff et al., 2007; Wanous et al., 1997). Rumination was also measured at the end of the experiment and thus may have been biased by retrospection. On the other hand, the alternative is also not without problems as we believe that the often used thought-sampling technique that measures thoughts repeatedly during the recovery period (Gerin et al., 2006; Key et al., 2008) is likely to interfere with or elicit rumination and, therefore, creates a less accurate picture of spontaneous rumination. Moreover, highly regarded and widely used questionnaires such as the Beck Depression Inventory (BDI; Beck & Beck, 1972) or the Maslach Burnout Inventory (MBI; Maslach et al., 1996) use retrospective techniques to measure thoughts and events in the recent past.

An interesting question for future research is whether or not a manipulation of rumination would facilitate or impede cardiovascular recovery. Earlier research has shown that rumination about negative events could be decreased by bringing one's attention to the present moment, rather than dwelling on past negative events (Borders et al., 2010), by restoring a positive self-image after a negative experience (Koole et al., 1999), or by reducing beliefs about the usefulness of rumination (Moulds et al., 2010).

Strengths and practical implications

Despite these limitations, the current research contributed to understanding the process of recovery from stress by examining the linkages between 'subjective' psychological processes and 'objective' physiological processes. This study is one of the first to examine the role of negative and positive affect in cardiovascular recovery from stress and to provide evidence that negative affect impedes cardiovascular recovery from stress. In addition, we demonstrated that rumination impeded cardiovascular recovery. Thus, the current research advanced insight in the importance of affect and rumination in stress recovery.

In practice, the current research implies that after a stressful experience, it is important to avoid activities or experiences that cause negative affect and engage in activities that distract thoughts from the stressful experience and prevent rumination. In this way, one can psychologically and physiologically recover from stress and preserve health.

Acknowledgements

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Music and psychophysiological recovery from stress

ABSTRACT

This experimental study examined whether listening to self-chosen music after stress exposure improves mood, decreases subjective arousal and rumination, and facilitates cardiovascular recovery. Participants (N = 123) were exposed to a mental arithmetic task with harassment to induce stress. Afterward, participants were randomly assigned to one of four 'recovery' conditions where they (1) listened to self-chosen relaxing music, (2) listened to self-chosen happy music, (3) listened to an audiobook, or (4) sat in silence. After this 5-minute 'recovery manipulation period', participants sat in silence for another 5 minutes. Systolic blood pressure, diastolic blood pressure, and heart rate were continuously measured. Results revealed that the recovery conditions caused differences in positive affect and negative affect. As expected, mood improved while listening to either relaxing music or happy music. The conditions showed no differences in subjective arousal and rumination. Systolic blood pressure recovery, however, differed between the conditions. Listening to both relaxing and happy music delayed systolic blood pressure recovery when compared with both control conditions. To conclude, listening to self-selected music is an effective mood enhancer, but it delays blood pressure recovery.

Based upon:

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INTRODUCTION

Recovery from stress is an essential part of a healthy lifestyle (Geurts & Sonnentag, 2006). Poor stress recovery has been related to health threats such as hypertension (Hocking Schuler & O'Brien, 1997) and even cardiovascular death (Kivimäki et al., 2006). The adverse health effects of incomplete recovery can be understood from the perspective of Effort-Recovery theory (Meijman & Mulder, 1998). This theory posits that health is not jeopardized as long as stress-related psychophysiological activation returns to prestressor levels relatively shortly after the stressor had ended. However, when psychophysiological activation prolongs after stress exposure and does not return to prestressor levels, the total load on the individual exceeds the capacity to maintain an internal equilibrium (Meijman & Mulder, 1998). This has also been called 'allostatic load' (McEwen, 1998), which includes a disturbed sympathetic-parasympathetic balance that is an important factor in the development of hypertension and cardiovascular disease (Thayer et al., 2010).

As stress is characterized by high arousal and negative affect (Kristensen et al., 1998), one of the core functions in stress recovery is mood regulation. Mood regulation strategies aimed at redirecting cognitions and actions away from the stressor, the so-called diversion strategies (Parkinson & Totterdell, 1999), seem to be the most relevant strategies for stress recovery. Various studies have shown that being engaged in a distractive activity facilitates cardiovascular recovery from stress (Gerin et al., 2006; Glynn et al., 2002), whereas rumination about stressful events impairs cardiovascular recovery (Pieper et al., 2007; Radstaak et al., 2011). Diversion strategies may, on the one hand, help people to use thought-action repertoires focusing on targets different from the stressor and, on the other hand, induce positive affect. Positive affect also seems to facilitate cardiovascular recovery (Fredrickson et al., 2000). After a stressful speech preparation task, watching a film clip that elicited positive affect resulted in faster cardiovascular recovery than watching a negative or a neutral film clip (Fredrickson et al., 2000).

Music as a diversion strategy in psychophysiological recovery from stress

One of the main reasons why people listen to music is to regulate their emotions (Chamorro -Premuzic & Furnham, 2007) and to improve their mood (Juslin, 2010). Listening to music seems to be an effective diversion strategy. It is the second used method, after exercising, for tension reduction and mood improvement (Thayer et al., 2004), mostly aimed at becoming happy or relaxed (Goethem & Sloboda, 2011), and it seems to act as a distractor (Mitchell et al., 2006). The distracting effect of music has been demonstrated by clinical studies. Listening to music decreased anxiety and pain during surgery (Nillson, 2008). Moreover, music may be more effective than other cognitive distracters because participants who listened to their own preferred music showed a higher tolerance for pain as compared with participants who were exposed to a distracting task in which they had to add numbers (Mitchell et al., 2006). Because a cognitive distractor is able to redirect thoughts away from the stressor, music listening may well reduce or prevent worrying and ruminative thinking.

Because listening to music improves mood and is a potentially effective cognitive distractor, it is likely to facilitate psychophysiological recovery from stress as well. Indeed, a number of studies have provided evidence for this beneficial effect (Burns et al., 2002; Chafin et al., 2004; Khalfa et al., 2003; Labbé et al., 2007; Lai & Li, 2011). For instance, nurses who listened to self-selected soothing music for 30 minutes reported less stress and showed lower heart rate and cortisol levels after a workday as compared with nurses who sat in silence (Lai & Li, 2011). A study conducted in a laboratory setting revealed similar results: listening to relaxing music caused a more rapid decrease in cortisol levels after a stressful task than sitting in silence (Khalfa et al., 2003). There are indications that different music styles may have different effects on psychophysiological recovery. Listening to heavy metal was not beneficial for stress recovery, whereas listening to classical and self-selected relaxing music was. It reduced anxiety and increased relaxation (Labbé et al., 2007). Listening to classical music after a stressful event decreased systolic blood pressure and heart rate, whereas listening to pop, jazz, hard rock, or self-selected music did not (Burns et al., 2002; Chafin et al., 2004).

The different effects of music on stress recovery might be explained by differences in valence and arousal elicited by listening to the different music styles. The circumplex model of affect proposes that all affective states arise from two fundamental dimensions, that is, valence (positive or negative) and arousal (high or low) (Russell, 1980). Thus, music listening can induce emotions that vary on these two dimensions. Konečni (1982) argued that people listen to music to moderate their level of arousal resulting from earlier activities: people with high arousal prefer to listen to slow, quiet music, whereas people with low arousal prefer loud and fast music (Konečni, 1982). Because people will experience high arousal after a stressful event, listening to music that further increases arousal will probably have less recovery potential than listening to music that reduces arousal. As far as we know, no research explicitly examined whether music eliciting different levels of arousal has a differential effect on psychophysiological recovery.

The present study

The present study examined the impact of self-chosen music on psychophysiological recovery from stress. We used self-chosen music because research has shown that people's own choice of music has a greater affective impact on them than music they do not prefer to listen to (Juslin et al., 2008). The self-chosen music elicited either feelings of relaxation (further referred to as 'relaxing music') or happiness (further referred to as 'happy music'). Both types of emotions have a positive valence but differ in the degree of arousal, with relaxation being associated with relatively low levels of arousal and happiness with high levels of arousal (Russell, 1980).

Participants were exposed to a standard stress task to induce elevated blood pressure, accelerated heart rate, and negative affect. Afterward, participants listened to either self-chosen relaxing music or self-chosen happy music, or were assigned to one of two control conditions. In one control condition, participants listened to an audiobook, and in the other control condition, participants just sat in silence. We expected that after stress exposure, a) the relaxing and happy music conditions have a stronger mood improving effect than the two control conditions (*Hypothesis 1*); b) the relaxing music condition reduces subjective arousal to a higher extent than all other conditions (*Hypothesis 2*); c) the relaxing and happy music conditions act as cognitive distractors, thereby preventing rumination about the stress task to a higher extent when compared with the two control conditions (*Hypothesis 3*); and d) both music conditions, but particularly the relaxing music condition, show faster cardiovascular recovery as compared with the two control conditions (*Hypothesis 4*).

METHOD

Participants

Participants were 123 white undergraduates (9 were male, 114 were female; mean [*M*; standard deviation {*SD*}] age = 21.1 [4.1] years). They were randomly assigned to one of four recovery conditions: a) self-chosen relaxing music (n = 32), b) self-chosen happy music (n = 34), c) audio control (n = 31), or d) control (n = 26). Male and female participants were equally distributed per recovery condition ($\chi^2(3) = 0.87$, $p = .83$). Individuals diagnosed as having hypertension were excluded from participation. Reliable cardiovascular data were obtained from 118 participants.

Cardiovascular recording

During the experiment, systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) were continuously measured, using a noninvasive beat-to-beat blood pressure monitor (Finometer; Finapres Medical Systems BV [FMS], the Netherlands). This device has been shown to track intra-arterial readings extremely well, even during sudden changes of blood pressure and HR (Parati et al., 1989). This makes it useful for cardiovascular reactivity and recovery testing. Another advantage of this beat-to-beat measurement technique is the reliable measurement of blood pressure and HR because of the large number of measurements that are averaged (Gerin et al., 1993). The Finometer computes all cardiovascular variables using Beatscope Easy. This program integrates and controls for sex, age, body mass, and weight in calculating cardiovascular indices.

Stress task

The stress task, a mental arithmetic task with harassment, was based on a standard anger provocation task (Glynn et al., 2002). Participants were instructed to count back from 9000 in steps of 17. During counting, the experimenter interrupted the participants three times during the first minute. The experimenter told them to start over again (first interruption), then made a disapproving sound (second interruption), and told them that the task would be made easier by counting back from 9000 in steps of 13 (third interruption). In the remaining four minutes, participants were told that they counted back too slowly (fourth interruption), that they really needed to concentrate (fifth interruption), and that the task would be ended because they really showed no improvement (sixth interruption). The stress task lasted five minutes.

Questionnaire measures

Figure 3.1 depicts the schematic overview of the procedure including the repeated measurements.

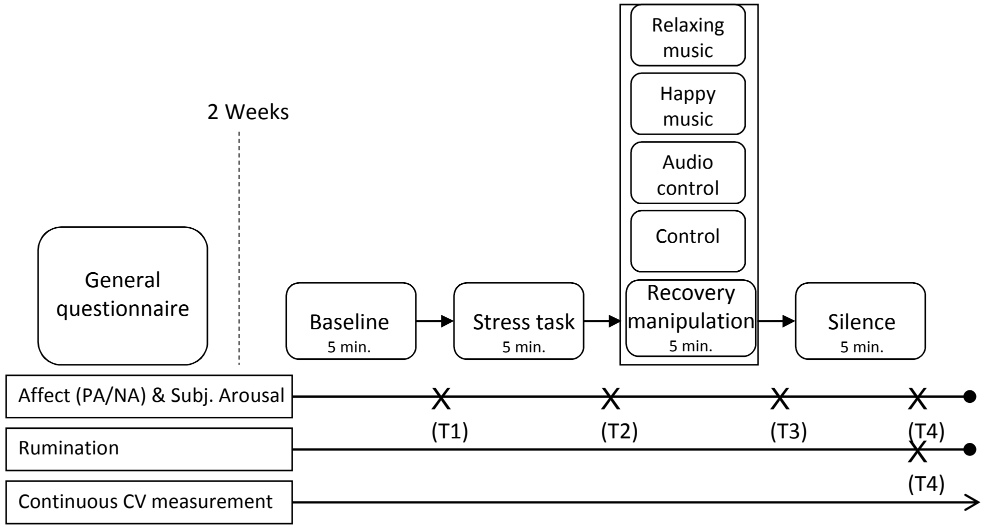
General music questionnaire. Participants were asked to list two music songs (titles and artist names) that made them feel relaxed and two music songs that made them feel happy. They also answered questions regarding demographic variables (age, sex).

Positive affect. Positive affect (PA) was measured four times during the experiment (see Figure 3.1), by using three items: “At this moment I feel [happy] [enthusiastic] [energetic]”. Items were rated on a 10-point Likert scale (1 = *strongly disagree*, 10 = *strongly agree*) and showed good reliability (Cronbach α = .78 - .90).

Negative affect. Negative affect (NA) was also measured four times (see Figure 3.1) by using three items: “At this moment I feel [tense] [angry] [irritated]”. Items were rated on a 10-point Likert scale (1 = *strongly disagree*, 10 = *strongly agree*). Except during baseline (α = .53), items showed good reliability (Cronbach α = .78 - .81).

Subjective arousal. The Self-Assessment Manikin (SAM) (Lang, 1980) was used to measure subjective arousal (SA) four times (see Figure 3.1). The SAM is a nonverbal self-report measure

Figure 3.1 Schematic overview of the design and procedure.



Note: X = measurement; CV = cardiovascular; PA = positive affect; NA = negative affect.

of arousal, using cartoon-like manikins. We used a nine figure SAM to represent nine intensity levels for arousal (1 = *very low arousal*; 9 = *very high arousal*). Research has shown that the SAM has good reliability and validity (Bradley & Lang, 1994).

Rumination. Rumination was measured once (see Figure 3.1) using four items. For rumination, we used the Dutch translation ‘piekeren’. In the Netherlands, piekeren is often used in popular language and refers to ‘worrying’ or ‘puzzling over negative events’. The first three items were as follows: “Since I finished the mental arithmetic task [I ruminated about the task] [I ruminated about my performance on the task] [I ruminated about the impression I left during the task]”. These items were rated on a 10-point Likert scale (1 = *strongly disagree*, 10 = *strongly agree*). The fourth item: “How much time did you spend ruminating about the mental arithmetic task”, was rated on a 10-point Likert scale with different labels (1 = *no time at all*, 10 = *the whole time*). The four items showed good reliability (Cronbach α = .90).

Procedure

Figure 3.1 shows the schematic overview of the procedure. About two weeks before the start of the experiment, participants completed an online questionnaire. Participants were asked to list their two favorite relaxing and happy songs, as well as two favorite books and movies. The last two questions were filler items and added to distract participants of the purpose of the study.

Participants provided their informed consent when arriving at the laboratory and were told that their blood pressure and HR would be monitored. Participants were placed in front of a laptop, the inflatable Finometer blood pressure cuff was placed on the third finger of the non-dominant hand, and participants were instructed to sit quietly and relax. The experimenter left the room and baseline blood pressure and HR levels were measured for five minutes. After five minutes, a questionnaire appeared on the computer screen in which baseline levels of affect and subjective arousal were measured (T1). When participants completed the questionnaire, the experimenter returned and started with the five-minute stress task, followed by a second online measurement of affect and subjective arousal (T2).

After the stress task, participants were randomly assigned to one of four ‘recovery’ conditions: (1) self-chosen relaxing music, (2) self-chosen happy music, (3) audio control, or (4) control. Participants in the relaxing music and happy music condition listened through headphones to self-chosen relaxing or happy music. Participants in the audio control condition listened through headphones to part of a Dutch audiobook, that is, the novel ‘Dooi’ (in English: thaw) written by Arthur Japin. All participants were instructed to sit quietly. Participants in the control condition were instructed to relax and wear no headphones. Once the experimenter was convinced that the instructions were understood, she left the room.

After five minutes, participants completed a third online measurement of affect and subjective arousal (T3). When participants completed this questionnaire, the experimenter returned to the room and instructed participants to relax for five more minutes. During these last five minutes of recovery (i.e., the silence period), the headphones were removed, there was neither music nor any other auditory stimuli, and the experimenter was not present. After this silence period, participants completed a fourth online measurement of affect and subjective arousal and a first measurement of rumination about the stress task (T4). At the end, the finger cuff was removed and participants were debriefed and thanked for their participation. They received money (€7.50) or course credit for participation. Data were collected in September and October 2012.

Musical features

As a manipulation check, we examined whether the musical features of the self-chosen 'relaxing' songs differed from musical features of the self-chosen 'happy' songs. All songs were scored on four musical features: mode (minor versus major), note density, timbre and tempo. These features were chosen because of their association with valence and arousal (Juslin, 2010; Gabrielsson & Juslin, 1996; Gomez & Danuser, 2007). All songs were independently judged by three musical experts (i.e., a professional saxophone player and two fourth-year students studying at the Conservatory) on three musical features using a 7-point Likert scale (mode: 1 = *minor*, 7 = *major*; note density: 1 = *low*; 7 = *high*; timbre: 1 = *round*, 7 = *sharp*). For tempo, the beats per minute were assessed using an online metronome. The intraclass coefficients calculated to assess interrater reliability were sufficient (Shrout & Fleiss, 1979): mode, 0.77; note density, 0.64, and timbre, 0.68. The correlations between the four musical features were small to moderate (all r values < 0.40).

Statistical analysis

To examine whether the stress task was effective, average SBP, DBP, and HR measures were computed for the baseline period and the stress task period (see Figure 3.1). Next, paired t tests were used to examine whether the stress task successfully decreased PA and increased NA, subjective arousal, blood pressure, and HR.

Multivariate analyses of variance (MANOVAs) were used to examine a) differences in musical features (dependent variables [DVs]: mode, note density, timbre, tempo; two between-participant factors: relaxing versus happy music); b) differences in affect, arousal, or cardiovascular indices during the baseline period; and c) differences in affect, arousal, or cardiovascular indices during the stress task period (DVs: PA, NA, SA, SBP, DBP, HR [T1 and T2]); d) changes in affect and subjective arousal after the five-minute recovery manipulation period (DVs: ΔPA, ΔNA, Δsubjective arousal [post-recovery manipulation [T3] scores minus post-stress task scores [T2]; see Figure 3.1]); and e) differences in affect and subjective arousal after the silence period (DVs: PA, NA, SA [T4]). An additional analysis of variance was used to examine differences in rumination (DV: Rumination [T4]). All analyses (except the MANOVA with musical features as DVs) had four between-participant factors (relaxing music versus happy music versus audio control versus control). Significant differences between the conditions were examined using

Bonferroni post hoc tests. If the results would reveal that participants in the four recovery conditions already differed in any of the study variables during the baseline period or the stress task period, this variable was added as a covariate to further analyses.

Growth curve modeling was used to examine the differences in cardiovascular recovery between the recovery conditions. This method was used because it is a flexible and powerful method for the analysis of change over time (Singer & Willet, 2003). Several steps were applied to examine whether the physiological data changed during the recovery manipulation period and whether potential differences remained during the silence period. First, all cardiovascular indices were averaged in parts of 15 seconds. Second, an unconditional means model (UMM) was fitted to the data. This model includes an intercept but no slope. Third, the linear time trend was added, in other words, an unconditional growth model (UGM) was fitted to the data. To examine whether model fit improved, the decrease in deviance was compared with the UMM. Fourth, the quadratic time trend was added, and the improvement in model fit was tested using the decrease in deviance compared with the UGM. Both models showed an improvement in model fit when the decrease in deviance was significant using χ^2-test. Separate analyses were run for SBP, DBP, and HR and for two different periods: a) recovery manipulation period and b) silence period (see Figure 3.1). To examine whether listening to relaxing or happy music would speed up cardiovascular recovery (SBP, DBP, and HR), the interaction between the possible time trends and recovery condition was added as a predictor to the multilevel model. The audio control condition was used as the reference group to which the other three recovery conditions (relaxing music, happy music, and control condition) were compared. This group was chosen as a reference group because participants in this condition were exposed to exactly the same procedure as participants in the two music conditions.

RESULTS

Preliminary results

Musical Features. The musical features differed between the relaxing music condition and the happy music condition ($F(4, 61) = 5.46$, $p = .001$, $\eta\rho^2 = 0.26$). As compared with happy music, relaxing music had a slower tempo ($F(1, 64) = 8.83$, $p = .004$, $\eta\rho^2 = 0.12$; relaxing music: M [SD] = 105.16 [27.98], happy music: M [SD] = 127.06 [31.64]), a lower note density ($F(1, 64) = 4.15$, $p = .046$, $\eta\rho^2 = 0.06$; relaxing music M [SD] = 4.44 [0.76], happy music: M [SD] = 4.84 [0.83]), was more often in minor key ($F(1, 64) = 5.49$, $p = .022$, $\eta\rho^2 = 0.08$; relaxing music: M [SD] = 3.96 [1.35], happy music: M [SD] = 4.76 [1.44]), and had a rounder timbre ($F(1, 64) = 8.58$, $p = .005$, $\eta\rho^2 = 0.12$; relaxing music: M [SD] = 3.42 [1.23], happy music: M [SD] = 4.27 [1.12]).

Stress induction. Table 3.1 presents the descriptives for positive and NA, subjective arousal, SBP and DBP, and HR for the total sample during the baseline period and the stress task period. NA, SA, SBP, DBP, and HR all increased significantly during the stress task period (NA: $\Delta M = 2.50$, $t(122) = -12.39$, $p < .001$, $d = -1.19$; SA: $\Delta M = 2.25$, $t(122) = -11.52$, $p \leq .001$, $d = -1.05$;

SBP: $\Delta M = 24.90$, $t(117) = -20.56$, $p \leq .001$, $d = -1.89$; DBP: $\Delta M = 15.94$, $t(117) = -27.84$, $p \leq .001$, $d = -2.61$; HR: $\Delta M = 12.94$, $t(117) = -15.64$, $p \leq .001$, $d = -1.48$). PA decreased significantly during the stress task period ($\Delta M = -1.15$, $t(122) = 8.23$, $p < .001$, $d = 0.75$). Hence, the stress task effectively induced stress, that is, NA and high psychophysiological arousal (Kristensen et al., 1998). In general, the effect sizes were large ($d > 0.80$) (Cohen, 1988).

Table 3.1 Descriptive statistics for affect, subjective arousal, rumination, and the cardiovascular indices.

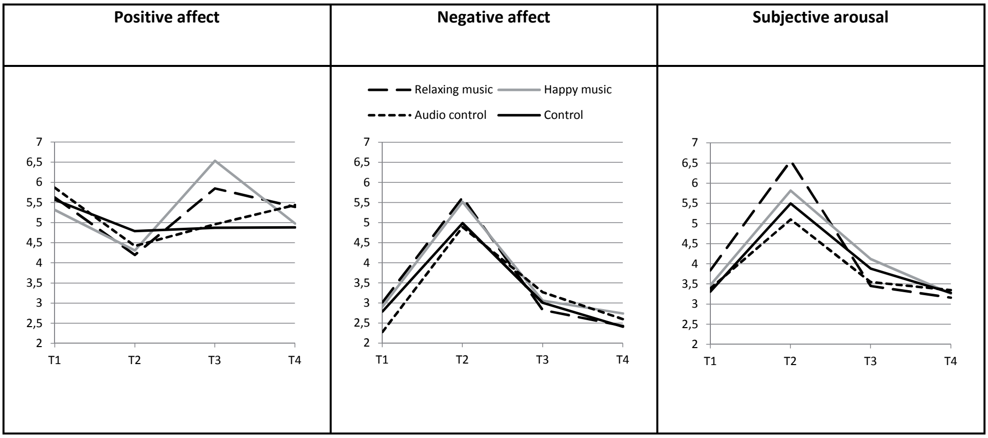
	Total		Relaxing music condition		Happy music condition		Audio control condition		Control condition	
	N	*M (SD)*	N	*M (SD)*	N	*M (SD)*	N	*M (SD)*	N	*M (SD)*
Positive affect (1-10)										
Baseline (T1)	123	5.58 (1.43)	32	5.63 (1.54)	34	5.32 (1.04)	31	5.57 (1.57)	26	5.87 (1.59)
After Stress Task (T2)	123	4.43 (1.69)	32	4.20 (1.73)	34	4.31 (1.65)	31	4.79 (1.58)	26	4.42 (1.85)
After recovery manipulation (T3)	123	5.61 (1.78)	32	5.85 (1.40)	34	6.54 (1.89)	31	4.87 (1.51)	26	4.96 (1.79)
After silence (T4)	122	5.16 (1.53)	32	5.39 (1.65)	34	4.98 (1.37)	31	4.88 (1.52)	25	5.44 (1.58)
Negative affect (1-10)										
Baseline (T1)	123	2.78 (1.13)	32	3.02 (1.14)	34	2.91 (1.05)	31	2.79 (1.21)	26	2.28 (1.03)
After Stress Task (T2)	123	5.28 (2.15)	32	5.63 (2.27)	34	5.52 (2.14)	31	4.99 (1.88)	26	4.89 (2.33)
After recovery manipulation (T3)	123	3.03 (1.57)	32	2.83 (1.41)	34	3.06 (1.39)	31	3.01 (1.60)	26	3.27 (1.98)
After silence (T4)	122	2.54 (1.28)	32	2.43 (1.34)	34	2.74 (1.26)	31	2.41 (1.06)	25	2.60 (1.50)
Subjective arousal (1-9)										
Baseline (T1)	123	3.51 (1.48)	32	3.84 (1.65)	34	3.47 (1.24)	31	3.39 (1.61)	26	3.31 (1.41)
After Stress Task (T2)	123	5.76 (1.91)	32	6.56 (1.80)	34	5.82 (1.71)	31	5.10 (1.99)	26	5.50 (1.92)
After recovery manipulation (T3)	122	3.75 (1.73)	31	3.45 (1.77)	34	4.12 (2.06)	31	3.55 (1.36)	26	3.88 (1.58)
After silence (T4)	122	3.26 (1.57)	32	3.16 (1.63)	34	3.26 (1.62)	31	3.35 (1.62)	25	3.28 (1.43)
Rumination (1-10)										
After silence (T4)	123	5.22 (2.45)	34	5.34 (2.54)	32	5.66 (2.65)	31	4.58 (2.08)	26	5.25 (2.47)
Systolic blood pressure (SBP)										
Baseline	118	117.47 (16.55)	31	121.54 (19.45)	33	117. 14 (15.51)	29	116.82 (15.44)	25	113.59 (15.04)
Stress Task	118	142.37 (15.34)	31	147.18 (18.19)	33	141.42 (12.24)	29	142.52 (16.21)	25	137.49 (13.10)
Diastolic blood pressure (DBP)										
Baseline	118	58.22 (11.16)	31	60.27 (13.18)	33	59.96 (10.82)	29	59.43 (9.55)	25	55.95 (10.60)
Stress Task	118	74.16 (9.78)	31	76.39 (12.20)	33	73.89 (8.94)	29	73.91 (8.99)	25	72.01 (8.26)
Heart rate (HR)										
Baseline	118	77.57 (12.91)	31	78.74 (10.39)	33	77.97 (14.19)	29	79.97 (12.08)	25	72.82 (14.35)
Stress task	118	90.51 (14.75)	31	91.21 (12.05)	33	93.20 (17.71)	29	92.04 (13.41)	25	84.34 (14.09)

In addition, MANOVA analysis showed that during the baseline period, the four recovery conditions did not differ in levels of negative or PA, SA, SBP, DBP, or HR (F(18, 309) = 1.01, p = .45, $\eta\rho^2$ = 0.05; PA: F(3, 114) = 0.67, p = .56, $\eta\rho^2$ = 0.02; NA: F(3, 114) = 2.39, p = .073, $\eta\rho^2$= 0.06; SA: F(3, 114) = 1.05, p = .37, $\eta\rho^2$ = 0.03; SBP: F(3, 114) = 1.11, p =.35, $\eta\rho^2$ = 0.03; DBP: F(3) = 0.95, p = .42, $\eta\rho^2$ = 0.02; HR: F(3, 114) = 1.58, p = .20, $\eta\rho^2$ = 0.04). In general, there were no differences between the four recovery conditions during the stress task period (F(18, 309) = 1.16, p = .30, $\eta\rho^2$ = 0.06). More specifically, there were no differences in negative or PA, SBP, DBP, or HR (PA: F(3, 114) = 0.81, p = .49, $\eta\rho^2$ = 0.02; NA: F(3, 114) = 0.91, p = .44, $\eta\rho^2$ = 0.02; SBP: F(3, 114) = 1.95, p = .13, $\eta\rho^2$= 0.05; DBP: F(3) = 0.95, p = .42, $\eta\rho^2$ = 0.02; HR: F(3, 114) = 2.00, p = .12, $\eta\rho^2$ = 0.05). However, there was a significant difference in the level of subjective arousal (F(3, 114) = 2.93, p = .037, $\eta\rho^2$ = 0.07). Immediately after the stress task, participants in the relaxing music condition already showed significantly higher subjective arousal (M = 6.48) than participants in the audio control condition (M = 5.10; p = .028). Therefore, subjective arousal after the stress task period (T2) was added as a covariate to the analysis that was used to examine the impact of the recovery conditions on subjective arousal.

Tests of Study Hypotheses

Changes in Mood and Subjective Arousal (Hypotheses 1 and 2). Table 3.1 and Figure 3.2 show the levels of PA, NA, and subjective arousal after the stress task period (T2), after the recovery manipulation period (T3), and after the silence period (T4). Because it is not possible to examine post hoc differences when a covariate is added to a MANOVA, subjective arousal was excluded from the analysis and analyzed separately. By this means, we could use post hoc analyses to examine differences in affect.

Figure 3.2 The development in positive affect, negative affect, and subjective arousal during the complete experiment (T1 to T4).



Note: T1: after 5 min. baseline period. T2: after 5 min. stress period. T3: after 5 min. recovery manipulation period. T4: after 5 min. silence period

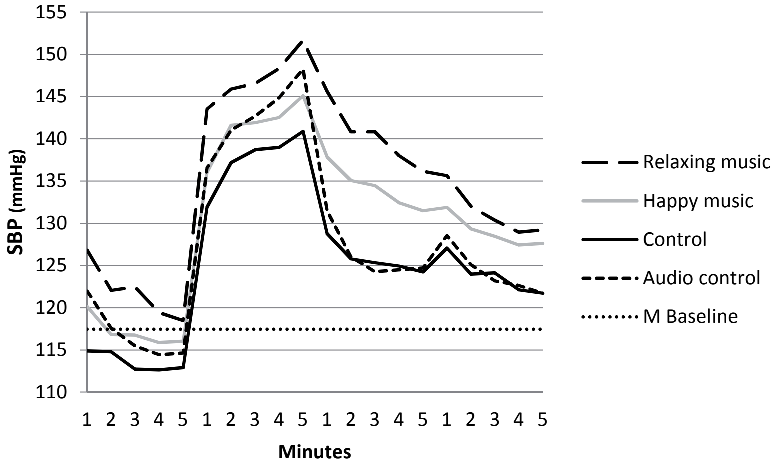
The MANOVA analysis with the changes in affect as dependent variables revealed significant differences between the recovery conditions (F(6, 236) = 6.77, p < .001, $\eta\rho^2$ = 0.15). Both the change in PA (F(3, 119) = 13.13, p < .001, $\eta\rho^2$ = 0.25) and the change in NA (F(3, 119) = 2.69, p = .049, $\eta\rho^2$= 0.06) differed between the conditions. Post hoc analyses revealed that the increase in PA was larger for participants in the relaxing music condition (ΔM = 1.66) as compared with those in the audio control condition (ΔM = 0.09; p = .001) and the 'all-silent' control condition (ΔM = 0.54; p = .039). Furthermore, the increase in PA was larger for participants in the happy music condition (ΔM = 2.23) as compared with those in the audio control condition (p < .001) and the control condition (p < .001). The decrease in NA was largest in the relaxing music condition (ΔM = -2.79) but differed only marginally from the decrease in NA in the control condition (ΔM = -1.62; p = .062), and not significantly from the decrease in NA in the other two conditions (happy music condition: ΔM = -2.46; p > .99; audio control condition: ΔM = -1.98; p = .37). There were no differences in the decrease in NA between the happy music condition and the audio control condition (p > .99) or the all-silent control condition (p = .36). After the silence period, participants in the four recovery conditions did not differ in levels of affect (F(6, 234) = 0.77, p = .59, $\eta\rho^2$ = 0.02).

To examine differences in subjective arousal, an analysis of variance was used with subjective arousal after the stress task period (T2) as a covariate (recovery manipulation period: F(1) = 108.98, p < .001, $\eta\rho^2$ = 0.48: silence period: F(1) = 16.23, p = .011, $\eta\rho^2$ = 0.06). During the recovery manipulation period, the decrease in subjective arousal did not differ between the four recovery conditions (F(3, 117) = 2.03, p = .11, $\eta\rho^2$ = 0.05), nor were there any differences after the silence period (F(3, 117) = 0.51, p = .68, $\eta\rho^2$ = 0.01).

Rumination (Hypothesis 3). Table 3.1 shows the degree of rumination after the silence period (T4). Levels of rumination did not differ between the four recovery conditions (F(3) = 1.10, p = .35, $\eta\rho^2$ = 0.03).

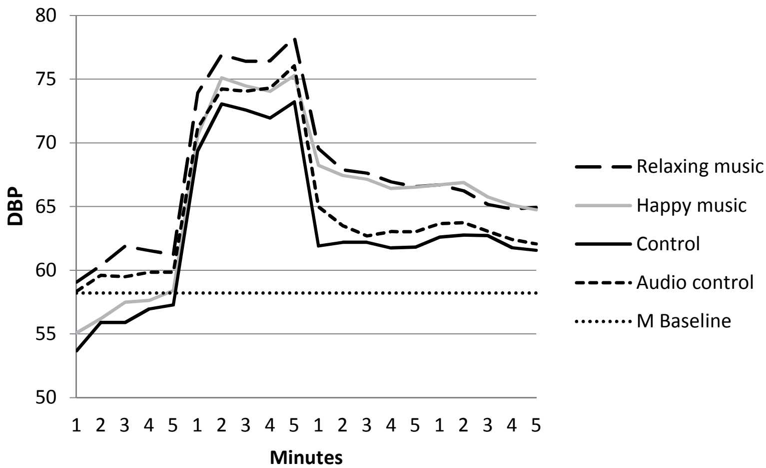
Cardiovascular Recovery (Hypothesis 4). Figures 3.3, 3.4, and 3.5 display the raw data of SBP (Figure 3.3), DBP (Figure 3.4), and HR (Figure 3.5). During the recovery manipulation period, adding the linear time trend to the UMM improved the model fit for SBP, DBP, and HR (SBP: $\chi^2(3)$ = -673.28, p < .001; DBP: $\chi^2(3)$ = -291.20, p < .001; HR: $\chi^2(3)$ = -288.83, p < .001). The linear changes in SBP and DBP were significant (SBP: b = -0.41, p < .001; DBP: b = -0.10, p < .001), whereas the linear change in HR was not significant (b = -0.01, p = .73). Post hoc analyses revealed that HR reached baseline levels (M = 77.57) within the first 30 seconds of the recovery manipulation period (M = 76.77; t(117) = 1.14, p = .26; see Figure 3.5). A significant time trend is a prerequisite to examine the process of stress recovery; therefore, the HR data were excluded from further analysis. Adding the quadratic time trend to the UGM improved model fit for SBP and DBP (SBP: $\chi^2(4)$ = -293.59, p <.001; DBP: $\chi^2(3)$ = -291.20, p < .001). Consequently, both the linear and quadratic time trends were added to the multilevel model. To examine Hypothesis 4, the interaction between recovery condition and both the linear and the quadratic time trend were added to the multilevel model.

Figure 3.3 Raw data of systolic blood pressure recovery during baseline (first 5 minutes), stress task (second 5 minutes) and the recovery manipulation period (third 5 minutes) and the silence period (last 5 minutes).



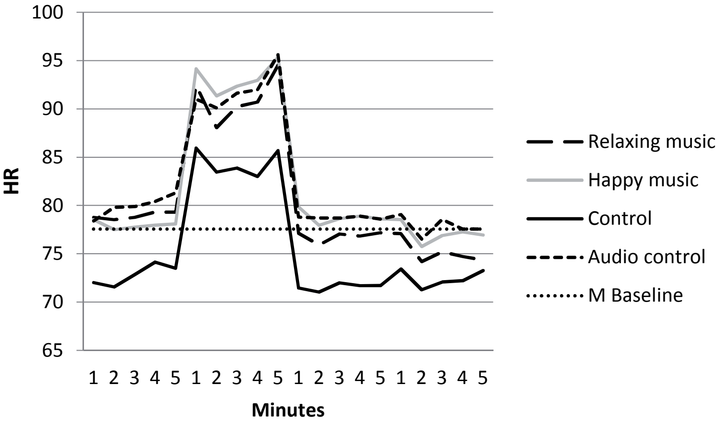
Note: *M* Baseline is the mean SBP for all conditions during the whole five minute baseline period. Baseline: *SD* Range: 12.86 (Control) to 23.01 (Relaxing music); Stress task: *SD* Range: 10.89 (Happy music) to 19.25 (Relaxing music); Recovery manipulation: *SD* Range: 11.58 (Control) to 19.23 (Audio control); Silence: *SD* Range: 9.56 (Control) to 17.33 (Relaxing music).

Figure 3.4 Raw data of diastolic blood pressure recovery during baseline (first 5 minutes), stress task (second 5 minutes) and the recovery manipulation period (third 5 minutes) and the silence period (last 5 minutes).



Note: *M* Baseline is the mean DBP for all conditions during the whole five minute baseline period. Baseline: *SD* Range: 9.23 (Audio control) to 14.82 (Relaxing music); Stress task: *SD* Range: 7.99 (Control) to 12.65 (Relaxing music); Recovery manipulation: *SD* Range: 6.25 (Control) to 12.87 (Relaxing music); Silence: *SD* Range: 5.96 (Control) to 11.87 (Relaxing music).

Figure 3.5 Raw data of heart rate recovery during baseline (first 5 minutes), stress task (second 5 minutes) and the recovery manipulation period (third 5 minutes) and the silence period (last 5 minutes).



Note: *M* Baseline is the mean HR for all conditions during the whole five minute baseline period. Baseline: *SD* Range: 9.83 (Relaxing music) to 16.40 (Control); Stress task: *SD* Range: 11.06 (Relaxing music) to 19.05 (Happy music); Recovery manipulation: *SD* Range: 8.52 (Relaxing music) to 15.96 (Happy music); Silence: *SD* Range: 8.03 (Relaxing music) to 12.79 (Happy music).

There were significant differences between the recovery conditions for SBP recovery (linear time trend: $F(3, 116) = 4.50$, $p = .005$; quadratic time trend: $F(3, 115) = 5.24$, $p = .002$), but not for DBP recovery (linear time trend: $F(3, 118) = 2.15$, $p = .10$; quadratic time trend: $F(3, 118) = 1.92$, $p = .13$). Table 3.2 depicts the estimates of the multilevel model for SBP and DBP recovery. Figure 3.6 is the visual display of the estimates of the multilevel model for SBP recovery. To examine the differences in SBP recovery between both music conditions and both control conditions, a repeated measures analysis of covariance was used with planned contrasts. To adjust for stress task levels of blood pressure, the last SBP assessment during the stress task was added as a covariate to the analysis. Dependent variables were mean SBP level during the first, second, third, fourth, and fifth minutes of the recovery manipulation period. During this whole period, blood pressure levels in both music conditions were higher than blood pressure levels in both control conditions ($F(5, 101) = 7.13$, $p <.001$, $\eta\rho^2 = 0.26$; first minute: $F(1, 105) = 16.42$, $p < .001$, $\eta\rho^2 = 0.14$; second minute: $F(1, 105) = 18.63$, $p <.001$, $\eta\rho^2 = 0.25$; third minute: $F(1, 105) = 26.66$, $p < .001$, $\eta\rho^2 = 0.20$; fourth minute: $F(1, 105) = 14.54$, $p < .001$, $\eta\rho^2 = 0.12$; fifth minute: $F(1, 105) = 11.23$, $p = .001$, $\eta\rho^2 = .10$). The same analysis, with different planned contrasts, revealed that there was no differences in SBP recovery between the relaxing music condition and the happy music condition ($F(5, 101) = 0.50$, $p = .77$, $\eta\rho^2 = 0.02$). Thus, listening to music delayed blood pressure recovery as compared with both control conditions.

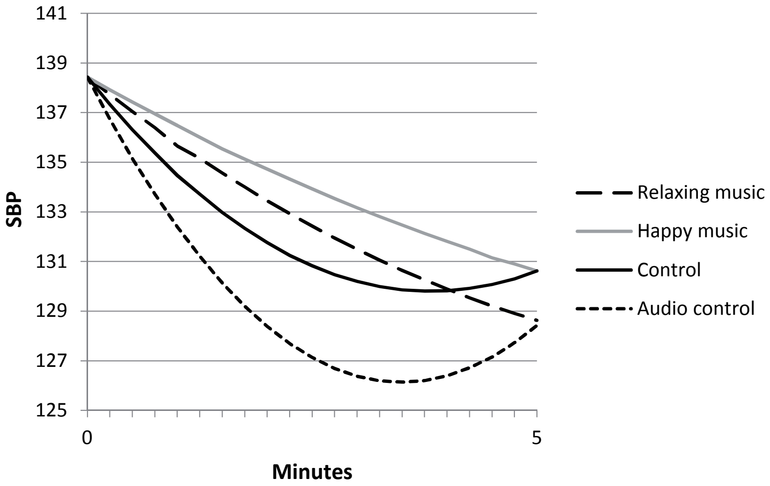
Table 3.2 Parameter estimates (per 15 seconds) of the multilevel model with SBP and DBP as dependent variables during the recovery manipulation period

	SBP, *b* (SE *b*)	DBP[1], *b* (SE *b*)
Fixed effects		
Initial status		
Intercept	138.43 (1.73)***	66.99 (1.01)***
Rate of change		
Time	-1.76 (.27)***	-.55 (.14)***
Time²	.63 (.12)***	.21 (.06)**
Linear change: 'Audio control' versus		
'Relaxing music'	1.05 (.37)**	.30 (.19)
'Happy music'	1.25 (.36)**	.41 (.19)*
'Control'	.63 (.39)	.43 (.20)*
Quadratic change: 'Audio control' versus		
'Relaxing music'	-.52 (.16)**	-.15 (.09)
'Happy music'	-.57 (.16)**	-.18 (.09)*
'Control'	-.26 (.17)	-.18 (.09)
Random effects		
Level -1		
Within-person	18.11 (.57)***	6.09 (.19)***
Level-2		
In initial status	108.58 (16.01)***	65.28 (9.10)
Time	2.04 (.34)***	.48 (.08)***
Time²	.34 (.06)***	.09 (.020)***
Fit statistics		
-2 log (likelihood)	14,334.2	11,840.7

SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; SE = Standard error.
All models were estimated under maximum likelihood.
**p* < .05, ** *p* < .01, ****p* < .001 (two-tailed).
[1]Because there were no main effects of recovery condition on the linear or quadratic DBP time trend, the parameter estimates of the differences between the conditions are redundant.

During the silence period, adding the linear time trend to the UMM improved model fit for SBP and DBP (SBP: $\chi^2(3) = -531.18$, $p < .001$; DBP: $\chi^2(3) = 315.70$, $p < .001$). The same was true for the quadratic time trend (SBP: $\chi^2(4) = -122.91$, $p < .001$; DBP: $\chi^2(4) = -25.32$, $p < .001$). However, during the silence period, there were no differences between the recovery conditions in SBP recovery (linear time trend: $F(3, 117) = .90$, $p = .45$; quadratic time trend: $F(3, 117) = 0.59$, $p = .63$) or in DBP recovery (linear time trend: $F(3, 117) = 1.08$, $p = .36$; quadratic time trend: $F(3, 117) = 1.34$, $p = .27$). This means that the differential effects of listening to self-chosen music faded out during the silence period.

Figure 3.6 Visual display of the estimates of the multilevel model for systolic blood pressure recovery during the recovery manipulation period.



DISCUSSION

Because incomplete recovery from stress is associated with serious health threats (Hocking Schuler & O'Brien, 1997; Kivimäki et al., 2006), it is important to understand this process. Because stress is characterized by high arousal and impaired mood (Kristensen et al., 1998), mood regulation is an essential element of stress recovery. The present study examined whether listening to music could be an effective diversion strategy by improving mood and decreasing stressor-related thoughts (Parkinson & Totterdell, 1999). We further hypothesized that listening to music could facilitate cardiovascular recovery from stress.

Music as diversion strategy

Previous research has shown that music is an effective mood regulator (Thayer et al., 2004; Goethem & Sloboda, 2011). In line with these findings, our results showed that listening to self-chosen relaxing and happy music increased positive affect, with effect sizes being large (relaxing music: d = -1.14, happy music: d = -1.08) (Cohen, 1988). Because previous research has shown that it is difficult to effectively induce positive mood - with mean effect sizes for mood improvement generally being small (d = 0.41) (Westermann et al., 1996) - our findings suggest that listening to self-chosen music is a particularly strong and effective mood enhancer, supporting our first hypothesis.

Our second hypothesis concerning subjective arousal was not supported because participants who listened to self-chosen relaxing music did not show the highest decrease in subjective arousal. A possible explanation for this finding is that participants selected the relaxing music themselves and thus listened to music they preferred. There are indications from previous research that listening to preferred music is associated with increased levels of subjective arousal (Salimpoor et al., 2009; Schäfer & Sedlmeier, 2011). The association between subjective arousal and music preference creates an interesting paradox with the view of Konečni (1982), who posits that people listen to music to moderate their levels of arousal. If people with high arousal prefer to listen to slow and quiet music, but preferred music normally increases arousal (Salimpoor et al., 2009; Schäfer & Sedlmeier, 2011), it might be hard to decrease levels of arousal by listening to music one prefers.

The third hypothesis that listening to music would prevent participants from ruminating after the stress task was not supported by our data. Earlier research showed that listening to classical, jazz, or pop music did not decrease rumination either (Chafin et al., 2004). Although music has been shown to be a successful cognitive distractor (Mitchell et al., 2006; Nillson, 2008), it is not necessarily associated with a decrease in stressor-related thoughts. We can even not exclude the possibility that listening to music increases stressor-related thoughts because listening to music may induce self-reflection. One of the reasons why people listen to music is to perceive one's thoughts and feelings more intensively (Schäfer & Seldmeier, 2009).

Music and cardiovascular stress recovery

Our fourth hypothesis was not supported because blood pressure recovery was not speeded up among participants who listened to self-chosen relaxing or happy music. In contrast to our expectations, systolic blood pressure recovery was delayed among participants who listened to self-selected music, regardless whether they listened to music that induced either low subjective arousal (i.e., relaxing music) or moderate subjective arousal (i.e., happy music). Two conclusions follow these findings. First, the subjective experience of arousal and the cardiovascular reaction to listening to music are not necessarily related. This finding corresponds with previous research (Schäfer & Sedlmeier, 2011). Second, our findings underline the importance of self-chosen music in cardiovascular recovery. Most research that examined listening to music in relation to stress recovery used music that was researcher selected for the particular experiment and not selected by the participants (Chafin et al., 2004; Khalfa et al., 2003; Lai & Li, 2011). The few studies that did examine the effects of self-selected music focused on heart rate recovery and did not find beneficial effects either (Burns et al., 2003; Labbé et al., 2007). More specifically, there were no differences in heart rate recovery among participants who listened to heavy metal, classical music, self-selected relaxing music or who sat in silence (Labbé et al., 2007), and heart rate was even elevated among listeners to self-selected relaxing music as compared with listeners to researcher-selected classical music (Burns et al., 2003). These findings suggest that listening to self-chosen music may impede rather than facilitate blood pressure recovery after stress exposure.

Listening to relaxing music affected systolic blood pressure recovery but not diastolic blood pressure recovery. A possible explanation for this finding is that the stress task, a mental arithmetic task with harassment, is an 'active' task that may have induced stronger cardiac than vascular responses (James et al., 2012), and cardiac responses are more strongly related to changes in systolic blood pressure than to changes in diastolic blood pressure (Kannel et al., 1971). It is unlikely that differences in reliability of the measurement of systolic blood pressure and diastolic blood pressure recovery caused the differential effect because previous research has shown that the measurements of systolic blood pressure and diastolic blood pressure are equally reliable (Schutte et al., 2004).

Suggestions for future research

Future research might examine the effect of non-chosen relaxing or happy music on cardiovascular recovery. Research examining the effects of listening to music on blood pressure recovery is scarce, and non-chosen music might be more beneficial for stress recovery than listening to self-chosen music. Non-chosen music does not increase subjective arousal as preferred music does (Salimpoor et al., 2009; Schäfer & Sedlmeier, 2011) and constitutes a novel stimulus unlike self-chosen preferred music. Previous research has shown that novel stimuli may capture attention to a stronger degree than familiar stimuli (Johnston et al., 1990). In other words, listening to non-chosen might be more distractive than self-chosen music and thereby facilitate cardiovascular recovery after stress exposure (Gerin et al., 2006; Glynn et al., 2002).

We cannot conclude or exclude that listening to music affects rumination, because we only measured rumination after the 10-minute silence period. Just as the effects of positive and negative affect faded, it might be that when measures would have been taken immediately after listening to music, different levels of rumination between the recovery conditions would have been observed. For future research, we could consider to measure rumination directly after the recovery manipulation period (T3). This way, the measurement would be taken before the fading-out process has been completed.

Although previous research has shown the beneficial effect of positive affect on cardiovascular recovery (Fredrickson et al., 2000), the results in our experiment did show that music listeners reported the highest level of positive affect, but did not show speeded-up blood pressure recovery. It might still be true that positive affect facilitates cardiovascular recovery, but may be particularly when it co-occurs with low levels of ruminative thinking. A third suggestion for future research is, therefore, to enhance the potentially distracting effect of music listening by instructing participants to consciously focus their attention to the music, thereby reducing ruminative thinking about the previous stressor and enhancing its potentially recovering effect.

Conclusions

The current research adds to the understanding of the process of stress recovery by examining the associations between listening to self-chosen music, mood, subjective arousal, rumination, and cardiovascular recovery after stress exposure. The results of this study suggest that listening to self-chosen relaxing and happy music is an effective mood enhancer, but it delays SBP recovery. These findings raise the question of whether listening to music one prefers adds to the process of unwinding from stress. Although listening to preferred music feels good, it does not benefit cardiovascular recovery.

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Source of funding and conflicts of interest

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Work stressors, perseverative cognition and objective sleep quality: A longitudinal study among Dutch Helicopter Emergency Medical Service (HEMS) pilots

ABSTRACT

This longitudinal study examined the associations between work stressors, perseverative cognition and subjective and objective sleep quality. We hypothesized work stressors to be associated with (i) poor nocturnal sleep quality and (ii) higher levels of perseverative cognition during a free evening. We further hypothesized (iii) perseverative cognition to be associated with poor nocturnal sleep quality and (iv) the association between work stressors and sleep quality to be mediated by perseverative cognition. The participants were 24 pilots working for the Dutch Helicopter Emergency Medical Service (HEMS). They completed six questionnaires: at the end of three consecutive day shifts and each morning following the shifts. The questionnaires addressed work stressors (workload, distressing shifts and work-related conflicts), subjective sleep quality and perseverative cognition. Participants wore actigraphs to assess sleep onset latency, total sleep time and number of awakenings. Correlation analysis revealed that (i) distressing shifts were related to delayed sleep onset and that workload was related to impaired subjective sleep quality. Moreover, (ii) distressing shifts were positively related to perseverative cognition, (iii) perseverative cognition delayed sleep onset and (iv) mediated the association between distressing shifts and sleep onset latency. To conclude, perseverative cognition may be an explanatory mechanism in the association between work stressors and poor sleep.

Based upon:

Radstaak, M., Geurts, S. A. E., Beckers, D. G. J., Brosschot, J. F., Kompier, M. A. J. (2014). Work stressors, perseverative cognition and objective sleep quality: A longitudinal study among Dutch Helicopter Emergency Medical Service (HEMS) pilots. *Journal of Occupational Health, 56,* 469 – 477.

INTRODUCTION

Recovering from stress is essential to uphold health and well-being (Geurts & Sonnentag, 2006). Research has shown that poor recovery is related to serious health threats such as hypertension (Hocking Schuller & O'Brien, 1997) and even cardiovascular death (Kivimäki et al., 2006). The crucial role of incomplete recovery can be understood from the perspective of the Effort-Recovery (E-R) theory (Meijman & Mulder, 1998). This theory suggests that people invest effort when dealing with work-related demands or stressors. This effort investment is associated with psychophysiological load effects, such as fatigue, from which people need to recover. As long as complete recovery occurs, that is, psychophysiological activation returns to baseline levels before effort is required again, health is not at risk. However, when psycho-physiological activation is prolonged and does not return to baseline levels, load effects may accumulate over time and may jeopardize the precarious internal equilibrium, which could be a serious health risk (McEwen, 1998; Meijman & Mulder, 1998).

Sleep is the most important recovery opportunity and essential to restore energy and replenish psychophysiological resources (Porkka-Heiskanen et al., 2003). Previous research has shown that a good night's sleep was associated with lower levels of negative affect and fatigue and a higher degree of positive affect and serenity in the morning (Sonnentag et al., 2008), whereas poor sleep quality has been associated with severe health impairments such as reduced immune functioning (Bryant et al., 2004), heart diseases (Schwartz et al., 1999), and even mortality (Kripke et al., 2002). Sleep deprivation is also a major cause of errors and accidents during work time (Wickens et al., 2003).

Work stress can be an important cause of poor sleep quality, but there are surprisingly few studies examining the causal relationship between work stressors and sleep problems (Van Laethem et al., 2013). There are, however, quite a number cross-sectional studies providing support for an association between work stress and impaired sleep (Kalimo et al., 2000; Lallukka et al., 2010; Park et al., 2013; Utsugi et al., 2005). For instance, high work strain, defined as the combination of high work demands and low job control, has been associated with a higher prevalence of disturbed sleep (Kalimo et al., 2000) and more sleep complaints (Lallukka et al., 2010; Utsugi et al., 2005), and high cognitive and emotional demands at work have been associated with an increase in sleep problems (Park et al., 2013).

Another study examining the associations between work strain and sleep quality found that the most important correlates of sleep quality were not job demands or job control but the inability to stop thinking about work (Åkerstedt et al., 2002). These results suggest that the inability to mentally switch off from work during leisure time may be an important factor in the relationship between work stressors and impaired sleep. This inability has also been referred to as perseverative cognition (Brosschot et al., 2006). Perseverative cognition, the repeated or chronic activation of the cognitive representation of one or more psychological stressors, keeps the stressors 'alive' and thereby the individual in a prolonged or reactivated state of psychophysiological arousal (Brosschot et al., 2006). This state can be expected to interfere with sleep (Morin et al., 2003).

As yet, surprisingly few studies have actually examined the role of perseverative cognition in the relationship between work stressors and impaired sleep. A recent cross-sectional study revealed that work stressors and perseverative cognition were negatively related to subjective sleep quality (Kompier et al., 2012). Another cross-sectional study with effort-reward imbalance and time pressure as work stressors and subjective sleep quality as the dependent variable, found that perseverative cognition mediated the association between work stressors and subjective sleep quality (Berset et al., 2010). A longitudinal study among school teachers found that teachers in high strain jobs ruminated more after work and reported poorer subjective sleep quality as compared with their counterparts in low strain jobs. However, rumination was not a mediator in the relationship between job strain and sleep quality (Cropley et al., 2006). More recently, a longitudinal study that examined work-related worrying as a mediator in the association between social exclusion at work and an objective measure of sleep quality, that is, sleep fragmentation, did not find proof for mediation either (Pereira et al., 2013).

In sum, there are only a few studies examining the associations between work stressors, perseverative cognition and sleep disturbances, most of which built upon cross-sectional designs and the results are inconclusive. The aim of the current study was to better understand the relations between work stressors, perseverative cognition and sleep by using a longitudinal design with repeated measures and a multifaceted sleep quality measure, including subjective and objective sleep quality indicators. In this study, we will specifically focus on sleep onset latency because the association between perseverative cognition and delayed sleep onset has been consistently shown in previous research (Harvey, 2004).

We hypothesized that exposure to daily work stressors is associated (i) with poor nocturnal sleep quality (*Hypothesis 1*) and (ii) with higher levels of perseverative cognition during a free evening (*Hypothesis 2*). We further hypothesize that (iii) perseverative cognition is associated with poor nocturnal sleep quality (*Hypothesis 3*) and that (iv) the negative impact of work stressors on nocturnal sleep quality is mediated by perseverative cognition during a free evening (*Hypothesis 4*).

The participants included in our study were Dutch Helicopter Emergency Medical Service (HEMS) pilots. HEMS provides 24/7 on-scene assistance to trauma patients. To provide this assistance, HEMS pilots work according to a compressed work schedule for approximately 40 hours over the course of three consecutive days, with each shift being almost 13 hours and modest time to recover between shifts. HEMS pilots were considered an appropriate population for this study's purposes because of their demanding psychosocial work environment. Their work requires high cognitive effort (Watson et al., 1996) and includes high emotional demands (Blau et al., 2012) and a highly unpredictable workload. Irrespective of their demanding work characteristics, HEMS pilots reported relatively high levels of well-being in a previous study which suggests that they were healthy and felt competent to do their jobs (Radstaak et al., 2014).

METHOD

Participants

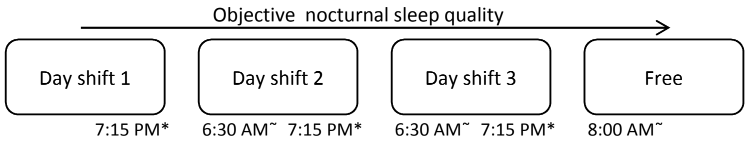
This study was part of a larger study into well-being and stress recovery among Dutch HEMS pilots (Radstaak et al., 2014). The general aim of the study and the importance of participation were explained to the total population of 27 HEMS employees during an introductory meeting. Participation in this study was voluntary. Twenty-four employees agreed to participate (response rate = 89%). One employee took part in the pilot study to test the procedure. Therefore, the data of 23 employees are reported here. One participant was female and the mean age of the participants was 44.1 years (*SD* = 5.97). All participants had a college or university degree. Participants worked according to a compressed shift work schedule for three consecutive day or night shifts with at least three free days between series of shifts. In the current study, we concentrated on day shifts because we were interested in the determinants of sleep quality within a normal sleep pattern (i.e., nocturnal sleep quality). All day shifts started at 6.30 AM. Participants worked during the first shift on average 13.15 hours (*SD* = 0.40), during the second day shift on average 12.75 hours (*SD* = 0.33) and during the third day on average 12.70 hours (*SD* = 0.52). This resulted in an average number of contractual hours per week of 38.6 hours (*SD* = 0.82), with a minimum of 37.0 and a maximum of 39.5 hours. The mean number of flight missions were 2.39 (*SD* = 1.69), 2.74 (*SD* = 1.60) and 2.83 (*SD* = 1.64) during the first, second and third day shifts, respectively. When the pilots were not called upon, they engaged in other work activities such as tracking flight and weather conditions and administrative work. They also had the opportunity to rest.

Procedure

For a schematic overview of the procedure, see Figure 4.1. Note that the design only involves day shifts because we concentrated on nocturnal sleep quality in this study. At least two weeks before the selected series of day shifts, participants received an e-mail in which they were informed in detail about the procedure of the study. It included an overview of the measurement dates, an individual log-in code to complete online questionnaires and an invitation to fill out a general questionnaire. This online questionnaire covered age, gender, education level and number of contractual work hours. After agreeing to participate on their respective measurement dates, the participants were given a tailor-made time schedule with an overview of their individual measurement dates and times.

Participants completed short questionnaires at the end of each day shift for three consecutive days and also in the three mornings following the day shifts (see Figure 4.1). Workload, distressing shifts and work-related conflicts were measured at the end of the three day shifts.

Figure 4.1 Schematic overview of the procedure.



Note: *Measurement of work stressors (workload, distressing shifts and work-related conflicts). ˜Measurement of perseverative cognition and subjective sleep quality.

Perseverative cognition and subjective sleep quality were measured before the start of the second and third day shifts and in the morning of a succeeding day off. This resulted in a total of six measurements per participant.

On each measurement occasion, the participants received an e-mail with a link to the questionnaire and a reminder text message on their cell phones at the exact moment when they had to complete the questionnaire. One and a half hours after sending the e-mail and text message, we checked whether the participants had completed the questionnaire. If they had not, they received a second text message that reminded them to fill out the questionnaire. After the participants had completed the last questionnaire, they were thanked for their participation and informed about when preliminary results were expected. This procedure resulted in 100% of the questionnaires being completed. The data were collected from March to August 2012.

Diary questionnaire measures

For all measurements, except the measurement of work-related conflicts, we used response-scales based on the Dutch grade notation system ranging from 1 (extremely low/negative) to 10 (extremely high/positive) and verbally anchored the first and last grades. Single-item measures were used to ensure user-friendliness by minimizing the effort required to complete the questionnaires at each measurement moment. When one-dimensional unambiguous constructs are measured, single-item measures are a legitimate alternative to multiple-item measures (Van Hooff et al., 2007).

Workload. Workload was measured at the end of each day shift, resulting in a total of three measurements, using the following item: “How busy were you during your shift?”. This item was rated on a 10-point Likert scale (1 = *not busy at all*, 10 = *very busy*).

Distressing shifts. Distress during shifts was measured three times. At the end of each day shift, participants answered the following item: “How distressing was your shift?”. This item was rated on a 10-point Likert scale (1 = *not distressing at all*, 10 = *very much distressing*).

Work-related conflicts. Participants indicated whether they experienced a conflict during their shift by answering the following question at the end of each shift, resulting in three measurements: “Did you experience a conflict during your shift?”. Participants responded to this question with *yes* (1) or *no* (0).

Perseverative cognition. Two items were used to measure perseverative cognition: "Yesterday evening, did you ruminate about your work?" and "Yesterday evening, did you worry about your work?". Items were rated on a 10-point Likert scale (1 = *not at all*, 10 = *very much*). For each participant, perseverative cognition was measured in the morning after each day shift, resulting in a total of three measurements, and the mean of the two items was calculated per measurement moment. With the exception of the first measurement (Cronbach's α = 0.47), the scale showed good reliability (Cronbach's α = 0.94 to 0.97).

Subjective sleep quality. Sleep quality was measured in the morning after each day shift, resulting in a total of three measurements. Participants indicated on a 10-point Likert scale (1 = *extremely poor*, 10 = *extremely good*) how they slept by answering the following question: "How well did you sleep last night?".

Objective sleep quality

A SenseWear Pro 3 Armband (BodyMedia, Inc., Pittsburgh, PA, USA) was used to measure sleep quality. The SenseWear armband is a multisensory body monitor, including a two-axis accelerometer and sensors measuring heat flux, galvanic skin response, skin temperature and near body ambient temperature. The device was worn over the triceps muscle of the right arm for the three consecutive days, both during the day and night, on which the questionnaires were administered. The data from the sensors were combined, using algorithms developed by the manufacturer (SenseWear professional software, version 6.1), to estimate sleep characteristics in one minute epochs. The SenseWear data were reduced to binary forms for 'lying down' ('0' = no, '1' = yes) and 'sleeping' ('0' = no, '1' = yes). The recommendations for standard sleep research were used to determine sleep onset latency, total sleep time and number of awakenings (Buysse et al., 2006). The SenseWear armband has been validated against polysomnography, which is considered to be the gold standard for the measurement of sleep quality. It has proven to be a reliable measurement of sleep quality in a healthy population and patients with obstructive sleep apnea (Sharif et al., 2013). The sleep quality data of 20 participants are reported here because three participants had trouble wearing the SenseWear armband (i.e., irritation of the skin).

Sleep onset latency. Sleep onset latency was measured as the time lag between lying down (i.e., change from '0' to '1' for 'lying') to the start of the sleep onset (i.e., change from '0' to '1' for 'sleeping').

Total sleep time. Total sleep time was defined as the total sum of the hours scored sleeping from sleep onset to the end of the sleeping episode.

Number of awakenings. The number of awakenings was the number of awake periods of at least one minute, excluding the final awaking before getting up.

Statistical analyses

Statistical analyses were performed with SPSS 19.0. First, the aggregated means were calculated. Next, we calculated the zero-order correlations between all study variables to examine the first three hypotheses. Given the limited number of observations, meaningful associations could easily be missed if statistical significance would be chosen as the sole criterion. Therefore, correlations >0.30, representing a medium effect size (Cohen, 1992), were considered meaningful and practically relevant. To test Hypothesis 4, significant associations between work stressors, perseverative cognition and sleep quality were examined using a bootstrap mediation procedure (Preacher & Hayes, 2008). The estimate of the indirect effect was derived from the mean of 5,000 bootstraps samples, which established a confidence interval for multiple indirect effects. Mediation was established when the confidence interval of the indirect effect did not include zero (Preacher & Hayes, 2008).

RESULTS

Descriptives

The descriptive statistics of work stressors, perseverative cognition and sleep quality are presented in Table 4.1. In general, participants reported intermediate levels of workload (*M* range 4.91 − 5.04), low levels of distress during shifts (*M* < 3.10) and very few work-related conflicts (total N=3). Because only three persons experienced conflicts, the prevalence was too low to draw valid conclusions, and work-related conflicts were excluded from further analysis. In general, participants reported low levels of perseverative cognition (*M* < 1.90). On average, it took participants less than ten minutes to fall asleep. In general, they awoke on average eight times during their sleep and slept less time during the first two day shifts (*M* < 5.69 hours) when compared with the third day shift (*M* = 6.61 hours).

Table 4.1 Descriptive statistics for work stressors, perseverative cognition and sleep quality

	Day shift 1		Day shift 2		Day shift 3		Total	
	N	*M (SD)*	N	*M (SD)*	N	*M (SD)*	N	*M (SD)*
Workload (1-10)	23	4.91 (2.70)	23	5.04 (2.55)	23	4.74 (2.49)	23	4.90 (2.00)
Distressing shifts (1-10)	23	2.74 (1.96)	23	3.09 (2.61)	23	2.83 (1.77)	23	2.88 (1.19)
Work-related conflicts (0-1)	23	0 (0.00)	23	0.09 (0.29)	23	0.04 (0.21)	23	0.04 (0.11)
Perseverative cognition (1-10)	23	1.57 (0.61)	23	1.85 (1.74)	23	1.89 (1.61)	23	1.77 (1.04)
Subjective sleep quality (1-10)	23	6.70 (1.74)	23	7.37 (1.11)	23	7.65 (0.98)	23	7.24 (0.93)
Sleep onset latency (minutes)	20	9.50 (13.34)	20	8.05 (9.21)	20	7.15 (7.09)	20	8.23 (6.80)
Total sleep time (hours)	20	5.68 (1.10)	20	5.39 (1.27)	20	6.61 (1.72)	20	5.89 (1.04)
Number of awakenings	20	7.55 (4.80)	20	6.45 (3.46)	20	10.85 (6.51)	20	8.28 (3.58)

Test of study hypotheses

Table 4.2 shows the zero-order correlations between the work stressors, perseverative cognition and subjective and objective sleep.

Work stressors are associated with poor nocturnal sleep quality (Hypothesis 1). Workload was associated with poor nocturnal subjective sleep quality (r = -0.42, p = 0.044) and though to a lesser extent, with sleep onset latency (r = 0.37, p = 0.11) and total sleep time (r = -0.33, p = 0.16). Workload was not associated with number of awakenings (r = −0.07, p = 0.77). Distressing shifts were significantly associated with a longer nocturnal sleep onset latency (r = 0.50, p = 0.026), but not with subjective sleep quality (r = 0.05, p = 0.82), total sleep time (r = −0.24, p = 0.30) or number of awakenings (r = −0.07, p = 0.77).

Work stressors are positively associated with perseverative cognition (Hypothesis 2). Distressing shifts were positively associated with perseverative cognition during a free evening (r = 0.62, p = 0.002). Workload, however, was not significantly associated with perseverative cognition during a free evening (r = 0.19, p = 0.35).

Perseverative cognition is associated with poor nocturnal sleep quality (Hypothesis 3). Perseverative cognition was associated with a longer nocturnal sleep onset latency (r = 0.74, p < 0.001) but was not significantly associated with any other of the sleep quality indicators (r = 0.18, p = 0.41 for subjective sleep quality; r = −0.25, p = 0.29 for total sleep time; r = 0.21, p = 0.38 for number of awakenings).

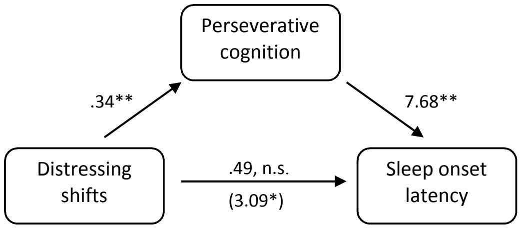
Table 4.2 Zero-order correlations between work stressors, perseverative cognition, and subjective and objective sleep

		N	1	2	3	4	5	6	7
1.	Workload (1-10)	23	-						
2.	Distressing shifts (1-10)	23	0.44*	-					
3.	Perseverative cognition (1-10)	23	0.19	0.62**	-				
4.	Subjective sleep (1-10)	23	-0.42*	0.05	0.18	-			
5.	Sleep onset latency (min)	20	0.37	0.50*	0.74**	-0.33	-		
6.	Total sleep time (hrs)	20	-0.33	-0.24	-0.25	0.11	-0.23	-	
7.	Number of awakenings	20	-0.07	0.16	0.21	-0.11	0.23	-0.36	-

Note: *p < .05, **p < .01.

Perseverative cognition mediates the association between work stressors and sleep quality (Hypothesis 4). Figure 4.2 displays the mediation model. Both distressing shifts and perseverative cognition were positively related to nocturnal sleep onset latency. Therefore, the mediation model was examined with distressing shifts as the ‘independent variable’, perseverative cognition as a mediator and sleep onset latency as the ‘dependent variable’. Replicating the correlation analysis, the mediation analysis revealed significant associations between distressing shifts and perseverative cognition (B = 0.34, p = 0.005), between perseverative cognition and sleep onset latency (B = 7.68, p = 0.004) and between distressing shifts and sleep onset latency (i.e., 'total effect': B = 3.09, p = 0.026). This latter association was no longer significant when perseverative cognition was controlled for (i.e., 'the direct effect': B = 0.49, p = 0.70). The 95% bias-corrected confidence interval for the size of the total indirect effect excludes zero [0.02, 5.99], suggesting a significant indirect effect (Preacher & Hayes, 2008). In other words and in support of our fourth hypothesis, perseverative cognition mediates the association between distressing shifts and sleep onset latency.

Figure 4.2 Mediation model.



Note: *p < .05, **p < .01. The value between parentheses indicates the 'total effect'.

DISCUSSION

Not being able to 'cognitively switch off' after a stressful workday may impede the most important recovery opportunity, that is, sleep. This study aimed to clarify this process by examining the associations between work stressors, perseverative cognition and objective and subjective sleep quality among a population with a demanding psychosocial work environment, that is, Helicopter Emergency Medical Service pilots who provide on-scene assistance to trauma patients.

Our first hypothesis was supported because we found distressing shifts to be associated with a longer time to fall asleep and workload to be associated with poorer subjective sleep quality, a longer time to fall asleep and shorter total sleep time. To our knowledge, there are only two previous field studies that have examined the associations between work stressors and an objective measurement of sleep quality, such as sleep actigraphy (Pereira et al., 2013; Dahlgren et al., 2005). However, the different operationalizations of the sleep quality indicators make a comparison of the results with and between the studies a difficult task. In our study, we found work stressors to be most strongly associated with sleep onset latency. Sleep onset latency was, however, not measured by Dahlgren and colleagues (2005). Pereira and colleagues (2013) did measure sleep onset latency in their study examining the associations between workplace social exclusion, worries and sleep. In their study, workplace social exclusion was not related to sleep onset latency, whereas it was positively related to fragmented sleep (Pereira et al., 2013). Because they used a different conceptualization of sleep fragmentation (i.e., the number of awakenings lasting five minutes or longer) than we did in the current study (i.e., the number of awake periods of at least one minute), it is hard to compare the results of both studies. Whereas it may be tempting to conclude that the occurrence of stressful workplace characteristics especially impacts sleep onset latency, further research with standardized operationalizations of crucial sleep parameters is needed to shed more light on this topic. Notwithstanding the need for more research examining work stressors in relation to objective sleep quality using the same conceptualization and utilization of different sleep quality indicators, research has consistently shown that work stress impairs sleep quality.

In support of the second hypothesis, distressing shifts were positively related to higher levels of perseverative cognition during a free evening. Workload was only weakly related to perseverative cognition (r = 0.19). These findings suggest that it is harder to unwind and recover from a distressing shift than from a busy shift. A possible explanation for why distressing shifts elicited higher levels of perseverative cognition is that distressing shifts are more emotionally charged than workload and induce a higher degree of negative affect. Research has shown that daily events that evoke a higher degree of negative affect induce a higher level of perseverative cognition too (Brans et al., 2013).

In line with our third hypothesis, perseverative cognition was associated with delayed sleep onset. It was not related to total sleep time or number of awakenings. The association between perseverative cognition and delayed sleep onset has been consistently shown in previous research (Harvey, 2004). For instance, it took good sleepers who were told to give a speech after their sleep period a longer time to fall asleep than those who did not have this assignment (Gross & Borkovec, 1982). In a similar vein, perseverative cognition about a stressor was associated with longer sleep onset latency but not with wake time, sleep duration or sleep fragmentation (Zoccola et al., 2009). These results support the assumption that perseverative cognition is primarily related to sleep-onset difficulties.

In support of our fourth hypothesis, we found perseverative cognition to be a mediator in the association between distressing shifts and sleep onset latency. Taken together, these associations support the ‘perseverative cognition hypothesis’ which states that repetitive thoughts about stressful events impede stress recovery (Brosschot et al., 2006). Work stressors increase psychophysiological activation not only during but also after work and in anticipation of a new work period. Accordingly, they deplete psychophysiological resources and cause a high need for recovery (Meijman & Mulder, 1998). At the same time, work stressors also induce perseverative cognition that impairs sleep quality. To break this vicious circle, employers should provide sufficient possibilities to recover during work time by ensuring employees have a variety of job-related duties, providing sufficient breaks, controlling the number of hours employees work and after work time by providing sufficient time to recover between shifts and series of shifts. Employees should preferably engage in activities that benefit recovery such as activities that induce positive affect (Van Hooff et al., 2011) and prevent thoughts about work stressors. Distraction has been shown to decrease physiological arousal after a stressful event (Glynn et al., 2002) and shorten sleep onset latency (Harvey & Payne, 2002).

Strong points and limitations

We believe that this study contributes to the literature on work stressors and sleep because it examines the associations between work stressors, perseverative cognition and objective sleep quality. It has high ecological validity because the use of actigraphy allowed us to examine sleep more objectively in a natural setting and in a minimally invasive manner. Another strength is that our sample covered almost the entire population of HEMS pilots in the Netherlands. The absence of attrition supports the validity of our results as well. All questionnaires were completed. This is probably due to proper introduction of the study and the use of short and user-friendly questionnaires with unambiguous and straightforward items to measure our constructs.

A limitation is that we measured perseverative cognition the morning after a night of sleep. Even though we asked the participants to indicate levels of perseverative cognition during the free evening and not when lying in bed, longer sleep onset latency could influence subsequent evaluations of perseverative cognition during the preceding evening. Also, we have no knowledge about the experiences participants had after they left the workplace. Social support from a spouse, for instance, may breach the association between work stressors and rumination (Viswesvaran et al., 1999). Therefore, future research should preferably study employees' experiences, activities and levels of perseverative cognition during off-job time in more detail by adding a measurement of these constructs before going to sleep.

HEMS pilots reported relatively low levels of total sleep time during the day shifts. These low levels raise the question of whether the pilots suffered from sleep deprivation. However, their relatively high levels of well-being at the start and at the end of the day shifts suggest that they felt healthy and capable of doing their jobs and that they did not suffer from sleep deprivation (Radstaak et al., 2014). Nevertheless, in follow-up research, it would be interesting to study their objective sleep quality and duration during recovery time, in other words, during their days off.

It is also important to note that we examined the associations between work stressors and sleep quality without appreciating the possibility of reverse causation. When an employee has sleep problems, there may be consequences for the psychosocial work environment. For instance, sleep problems may deplete energy recourses and intensify the consequences of work stressors (Zohar et al., 2003). Fatigued employees may also perform less well, make more mistakes and therefore receive criticism and less support (Spector et al., 2000). A lack of sleep may also influence the perceptions of stressors during a shift, even if the actual levels of stressors are the same. Thus, poor sleep quality might influence either the objective or perceived work environment. Still, even though sleep quality could influence work stressors, this does not refute our finding that work stressors are related to nocturnal sleep quality.

This study's focus on a specific group of employees raises the question of external validity of our findings. HEMS employees appeared to experience low levels of distress during their shifts and low levels of perseverative cognition during a free evening. However, that these low levels of work stressors and perseverative cognition were still significantly related to sleep onset latency only underlines the important role of work stressors and perseverative cognition for sleep quality.

Conclusion

This study indicates that perseverative cognition is an explanatory mechanism in the association between distressing work and poor sleep quality. Therefore, it is important to detach from stressful work experiences during leisure time because not being able to 'cognitively switch off' will impair sleep, the best recovery opportunity available. In practice, this implies that after a stressful workday, it is important to engage in activities that distract thoughts from the work stressors and prevent perseverative cognition.

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Source of funding and conflicts of interest

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5

Recovery and well-being among Helicopter Emergency Medical Service (HEMS) pilots

ABSTRACT

This study investigated the effects of a compressed working week with high cognitive and emotional work demands within the population of Dutch Helicopter Emergency Medical Service (HEMS) pilots. Work stressors were measured and levels of well-being were examined before, during and after a series of day and night shifts. Results revealed that (i) the start of a series of day shifts was more taxing for well-being than the start of a series of night shifts, (ii) there were no differences in the decrease in well-being during day and night shifts, (iii) distress during shifts was more strongly related to a decrease in well-being during night than during day shifts and (iv) it took HEMS pilots more time to recover from a series of night shifts than from a series of day shifts. It is concluded that HEMS pilots should not start earlier during day shifts, nor have longer series of night shifts.

Based upon:

Radstaak, M., Geurts, S. A. E., Beckers, D. G. J., Brosschot, J. F., Kompier, M. A. J. (2014). Recovery and well-being among Helicopter Emergency Medical Service (HEMS) pilots. *Applied Ergonomics, 45,* 986 – 993.

INTRODUCTION

Shift work is associated with a higher risk of accidents and ill health (Åkerstedt, 1990). These negative effects of shift work especially apply to night work and are mainly attributable to circadian disharmony (Åkerstedt, 1990, Costa, 1996; Smith et al., 2010). Night work disrupts the natural circadian rhythm because it requires people to be active at times when they would normally be sleeping, and vice versa. During night work, adaptation in circadian rhythm is limited (Ferguson et al., 2012). As a consequence, performance decreases (Burgess et al., 2013) and many shift workers suffer from insufficient and suboptimal sleep, resulting in incomplete recovery between shifts (Geurts et al., 2014). As feeling recovered is beneficial for performance during the next work day (Volman et al., 2013) and recovery has been argued to be a vital link between demanding work characteristics and employee health (Geurts & Sonnentag, 2006), incomplete recovery could be an important factor in the association between shift work and a higher risk of accidents and ill health.

The adverse effects of shift and night work could be particularly pronounced in the presence of additional demanding shift characteristics such as long work shifts (Rosa, 1995), varying workload that is either too low or too high causing passivity or high strain (Karasek, 1979), and high emotional (Maslach, 1982) and cognitive demands (Paas et al., 2003). These demands may deplete energy resources and thereby intensify the load effects and negative emotions caused by work stressors (Zohar et al., 2003). Such a combination of demanding shift work characteristics can be expected among employees working for ambulatory emergency services. In the current study, we examine a national population of such employees, that is, pilots working for the Dutch Helicopter Emergency Medical Service (HEMS). HEMS provides 24/7 on-scene assistance to trauma patients. To provide this assistance, HEMS employees work a compressed work schedule of circa 40 hours in three consecutive day or night shifts, with at least three free days between the series of shifts. HEMS pilots do not work a fixed pattern in the sequence of a series of day and night shifts, but generally their series of day and night shifts are alternated. The duration of one shift is long: almost 13 hours with a maximum duration of 15.5 hours per shift. During their shifts, they are called upon when an emergency happens and this makes their workload highly variable and unpredictable. During a mission, pilots are continuously interpreting information and making decisions that require high cognitive effort (Watson et al., 1996). In addition, HEMS employees are confronted with high emotional demands as they often encounter emotionally taxing situations such as driving accidents, heart attacks and falls (Blau et al., 2012). It is possible for HEMS employees to sleep during night shifts when they are not called upon.

The aim of the current study is to examine the effects of a compressed working week with high cognitive and emotional work demands in relation to well-being and recovery within the population of HEMS pilots. Although there are studies examining the economic costs and benefits of HEMS as a facility (for a review see Taylor et al., 2010), studies examining well-being and recovery of HEMS pilots themselves are rare. To our knowledge, this is the first study to examine well-being and recovery in this population. Four focal issues are central in this paper: (1) well-being at the start of a series of shifts, (2) well-being during a shift, (3) work characteristics and well-being during a shift, and (4) recovery after a series of shifts.

Well-being at the start of a series of shifts

Dutch HEMS personnel start their day shifts at 6:30 AM and their night shifts at 6:30 PM. The early start of day shifts requires an advancing of the body's timing system while the start of a series of night shifts requires a delaying of the body's timing system. Research shows that advancing, instead of delaying the body's timing system, is associated with more health complaints such as headache, irritability, gastrointestinal disorders, fatigue and loss of concentration (Waterhouse et al., 1997). Therefore, we expect that the start of a series of day shifts is associated with lower levels of well-being. More precisely, we hypothesize that at the start of a series of day shifts, well-being is lower than in the morning on a preceding day off. The start of a series of night shifts is not associated with lower levels of well-being when compared to levels of well-being on the evening of a preceding day off (*Hypothesis 1*).

Well-being during a shift

Empirical literature on long work hours has shown that long shifts increase fatigue and cause a higher risk of accidents and reduce performance (Rosa, 1995). Previous research has shown that these disadvantages seem to be most pronounced for night shifts (Smith et al, 1998; Rosa, 1995) and toward the end of long shifts (Folkard, 1997). As HEMS personnel work day and night shifts of almost 13 hours, we expect a significant decrease in well-being during individual shifts (*Hypothesis 2a*), and a higher decrease in well-being during night shifts when compared to day shifts (*Hypothesis 2b*).

Work characteristics and well-being during a shift

The decrease in well-being during shifts is not only determined by the length of a shift, but also by the work content and experiences during a shift. HEMS pilots can be expected to face relatively demanding work characteristics such as highly variable and unpredictable workload and emotional stressors. In previous research, such demanding work characteristics have been associated with low levels of well-being (de Jonge et al., 2008; Van der Doef & Maes, 1999). Moreover, the cognitive-energetic model of affective reactions posits that negative emotions following disruptive events are intensified when limited energy resources are available (Zohar et al., 2003). As night shifts cause a significant loss in sleep and deplete energy resources (Rosa, 1995), the negative emotions caused by work stressors could be intensified during the night. Therefore, our third hypothesis states that during night shifts, job stressors (workload as well as distress during shifts) are more strongly associated to a decrease in well-being than during day shifts (*Hypothesis 3*).

Recovery after a series of shifts

Over the last decades, awareness has risen that recovering from stress, during work or leisure, is important to preserve performance (Volman et al., 2013) and health (Geurts & Sonnentag, 2006). The small adaptations in circadian rhythm during night work (Ferguson et al., 2012) could result in a longer time needed to recover from a series of night shifts than from a series of day shifts. This longer recovery time could explain the adverse effects of night work (Åkerstedt, 1990, Costa, 1996; Smith et al., 2010), as slow and incomplete recovery impedes health and well-being (Meijman & Mulder, 1998). Our fourth hypothesis states that HEMS pilots need a longer time to recover from a series of night shifts than from a series of day shifts (*Hypothesis 4*).

METHOD

Participants

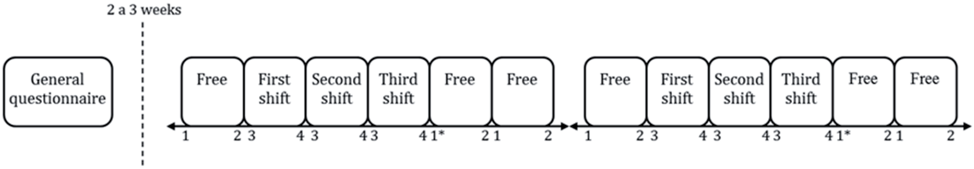
All 27 employees working for the Dutch HEMS were approached for participation. During an introductory meeting, the general purpose of the study and the importance of participation were explained to the HEMS employees. Twenty-four employees agreed to participate (89% of the total population). The data of 23 employees will be reported because one employee took part in a pilot study to test the procedure. Mean age of the participants was 44.1 years (*SD* = 5.97) and one of them was female. All participants had a college or university degree. In a compressed work schedule participants worked 38.6 contractual hours per week (*SD* = 0.82), with a minimum of 37 hours and a maximum of 39.5 hours.

Procedure

For a schematic overview of the procedure see Figure 5.1. Two to three weeks before a random series of day or night shifts, participants received an e-mail in which they were informed in detail about the study procedure. This e-mail included an overview of the measurement dates and an individual log-in code to complete online questionnaires. Participants were also invited to complete the online general questionnaire with questions concerning age, gender, education level and contract hours. When the participants agreed with the measurement dates, they received a tailor-made time schedule of their individual measurement occasions.

Before, during and after a series of day and night shifts, participants completed short online questionnaires measuring daily well-being, number of flight missions, workload and distress during shifts. During night shifts, on-job sleep quality was also measured. To be more precise, daily well-being was measured in the morning and evening on a free day (1 day*2 measurements) before a series of three consecutive shifts. During a series of shifts, participants completed a short questionnaire both at the start and at the end of each shift (3 days*2 measurements). Daily well-being was measured at the start and the end of each shift whereas number of flight missions, workload and distress during shifts were measured at the end of a

Figure 5.1 Schematic overview of the procedure.



Note: 1 = Measurement in the morning of a free day. 2 = Measurement in the evening of a free day. 3 = Measurement at the start of a shift. 4 = Measurement at the end of a shift. * During night shifts participants completed this measurement only when they took a nap after the shift.

shift. On-job sleep quality was only measured at the end of a night shift. After a series of shifts, daily well-being was measured in the morning and evening on two consecutive free days (2 days*2 measurements). This makes a total of 12 measurements of daily well-being and three measurements of number of flight missions, workload and distress during shifts. Because the same procedure was followed for a series of day and night shifts, the total number of measurements of daily well-being was 24 and number of flight missions, workload and distress during shifts were measured six times.

Participants received an e-mail with a link to the questionnaire at the exact moment when they had to complete the questionnaire. In addition, participants received a text message on their cell phones to remind them to fill out the questionnaire. One and a half hour after sending the e-mail and text message, it was checked whether participants had completed the questionnaire. If they had not, they received a second text message wherein they were reminded to complete the questionnaire. After participants filled out the last questionnaire, they were thanked for their participation and informed when preliminary results were expected. This procedure resulted in a total score of 99% completed questionnaires. The only two questionnaires that were not completed were a questionnaire at the end of night shift two and a questionnaire at the end of night shift three. The data were collected from March to August 2012.

Measures

For daily measurements, we adapted response-scales based on the basic Dutch grade notation system ranging from 1 (extremely low/negative) to 10 (extremely high/positive) and anchored the first and the last grade. The Dutch grade system considers a six as the lowest satisfactory score and a score below six is considered ‘unsatisfactory’. Single-item measures were used to minimize the effort required from the participants and maximize user-friendliness. When one-dimensional unambiguous constructs are measured, single-item measures are a legitimate alternative to multiple-item measures. The wording and face validity of the items were discussed with peer researchers and the participant who took part in the pilot study and a few ambiguous items were reformulated.

Daily well-being. Well-being was measured 24 times using six items. These items were adapted from the Health & Well-being measurement used by De Bloom et al. (2013). The items were: "At this moment, I feel [energetic] [happy] [relaxed] [tired] [stressed out] [irritated]". Items were rated on a 10-point Likert scale (1 =not at all, 10 =very much). The items [tired] [stressed out] and [irritated] were reverse scored and a mean well-being score was calculated per measurement moment. The items showed good reliability (Cronbach's α = .67 - 0.92, # of Cronbach's α < 0.75 = 4, # of Cronbach's α > 0.75 = 20).

Number of flight missions. Participants indicated per shift how much flight missions they had, by answering the question: "How many times did you actually fly during your shift?" Number of flight missions was measured six times.

Workload. Workload was measured six times using the following item: "How busy were you during the shift?", and rated on a 10-point Likert scale (1 = *not busy at all*, 10 = *very busy*).

Distress during the shift. Distress during shifts was measured six times using the following item: "How distressing was your shift?". The item was rated on a10-point Likert scale (1 = *not distressing at all,* 10 = *much distressing*).

On-job sleep quality. On job-sleep quality was measured after each night shift resulting in a total of three measurements. Participants indicated on a 10-point Likert scale (1 = *extremely poor*, 10 = *extremely good*) how well they slept during the night shift by answering the question: "How well did you sleep during your shift?".

Statistical analyses

The first hypothesis - at the start of a series of day shifts, well-being is lower than in the morning on a preceding day off, whereas the start of a series of night shifts is not associated with a decrease in well-being - was examined using a 2 (Day shifts: well-being at a free morning before a series of day shifts vs. well-being at the start of a series of day shifts) x 2 (Night shifts: well-being at a free evening before a series of night shifts vs. well-being at the start of a series of night shifts) repeated measures analysis of variance (RM-ANOVA). A significant interaction effect would indicate that the development of well-being, from a free day before a series of shifts to the start of a series of shifts, differed between day and night shifts. Post-hoc paired t-tests were used to further explore a significant interaction effect.

The second hypothesis - well-being decreases during individual day and night shifts with a higher decrease in well-being during night shifts - was examined using paired t-tests. Levels of well-being at the start of each shift were compared to levels of well-being at the end of each shift. To examine whether the decrease in well-being during night shifts is significantly higher than during day shifts, difference scores were calculated for each day shift (well-being at the end of a day shift - well-being at the start of a day shift) and each night shift (well-being at the end of a night shift - well-being at the start of a night shift). These difference scores for day and night shifts were compared using paired t-tests.

The third hypothesis - a stronger association between job stressors and decreases in well-being during night shifts than during day shifts - was examined using multilevel analysis. Multilevel analysis is a very useful analysis method for repeated measures because it corrects for the correlations between measurements within individuals (Hox, 2010). MLwiN 2.23 was used to conduct the analysis and all variables were standardized. Because we were interested in the decrease in well-being during a shift, we added well-being at the start of a shift as a covariate and well-being at the end of the shift was the dependent variable. Other covariates were number of flight missions and sleep quality (only for night shifts). Because the number of participants was small and we did not want to lose too much power, we had to be parsimonious in the estimated parameters. Therefore, we did not estimate the covariance parameters between day and night shifts which reduced the estimated parameters with nine (3 day shifts x 3 night shifts). We also assumed that the association between the independent variables and the dependent variable was the same during the three day shifts and during the three night shifts. By this means we reduced the estimated parameters with a factor three for day and night shifts: five parameters estimates instead of fifteen for day shifts (reduction of 10) and six parameter estimates instead of eighteen for night shifts (reduction of 12). Thus, in total we added thirty-one degrees of freedom per multilevel model. To examine whether the associations between job stressors and well-being differed for day and night shifts, three models were defined. Model A assumed that the associations between job stressors and well-being were different for day and night shifts. Model B assumed that the associations between workload and well-being were the same for day and night shifts. Model C assumed that the associations between distress during shifts and well-being were the same for day and night shifts. When Model B and/or C showed a decrease in model fit, the associations between job stressors and well-being for day and night shifts were considered to be different. The decrease of model fit was examined using χ^2-test.

To examine the fourth hypothesis - it takes a longer time to recover from a series of night shifts than from day shifts - we applied four steps. First, we calculated a baseline score for well-being before a series of day shifts by averaging levels of well-being on a free morning before a series of day shifts and levels of well-being on a free evening before a series of day shifts. The same method was used to calculate baseline levels of well-being before a series of night shifts. Second, we calculated the standard deviations for these two variables. Third, we estimated per participant how many hours it took them to recover after a series of day and night shifts. Participants were considered to be recovered when their levels of well-being was at minimum a half standard deviation below their baseline level of well-being. This means that during day shifts, it took participants 12 hours to recover when well-being reached baseline levels in the morning after a series of day shifts. It took them 24 hours to recover when well-being reached baseline levels in the evening after a series of day shifts and it took hem 36 hours to recover when well-being reached baseline levels the second morning after a series of day shifts. The same method was applied to night shifts. It took participants 12 hours to recover when they reached baseline levels of well-being the evening after a series of night shifts. When levels of well-being reached baseline levels the free morning after a series of night shifts, it took participants 24 hours to recover. It took them 36 hours to recover when they reached baseline levels of well-being in the evening of a free day. Because our recovery measurements were limited to a period of 36 hours after the series of shifts, we assumed that it took participants 48 hours to recover when they were not recovered within 36 hours. Fourth, a paired t-test was used to examine whether it took longer time to recover from night shifts as compared to day shifts.

RESULTS

Descriptives

Table 5.1 shows the descriptives of well-being before, during and after a series of day and night shifts. The descriptives of on-job sleep quality (only during night shifts), number of flight missions, workload and distress during shifts for both a series of day and night shifts are shown in Table 5.2. Tables 5.3 and 5.4 show the crude correlations between well-being, on-job sleep quality (only during night shifts), number of flight missions, workload and distress during shifts for day shifts (Table 5.3) and night shifts (Table 5.4). Levels of well-being during day and night shifts are depicted in Figure 5.2.

The descriptives in Tables 5.1 and 5.2 and Figure 5.2 show that in general, HEMS employees experienced high levels of well-being (Day shifts: $M > 7.67$; Night shifts $M > 7.45$). During their shifts, participants experienced moderate levels of workload (M range 3.41 - 5.04) and low levels of distress ($M < 3.09$). Sleep quality during the night was satisfactory during the first two night shifts ($M > 6.0$) but less satisfactory during the third night shift ($M = 5.86$).

Figure 5.2 Well-being before, during and after a series of day and night shifts.

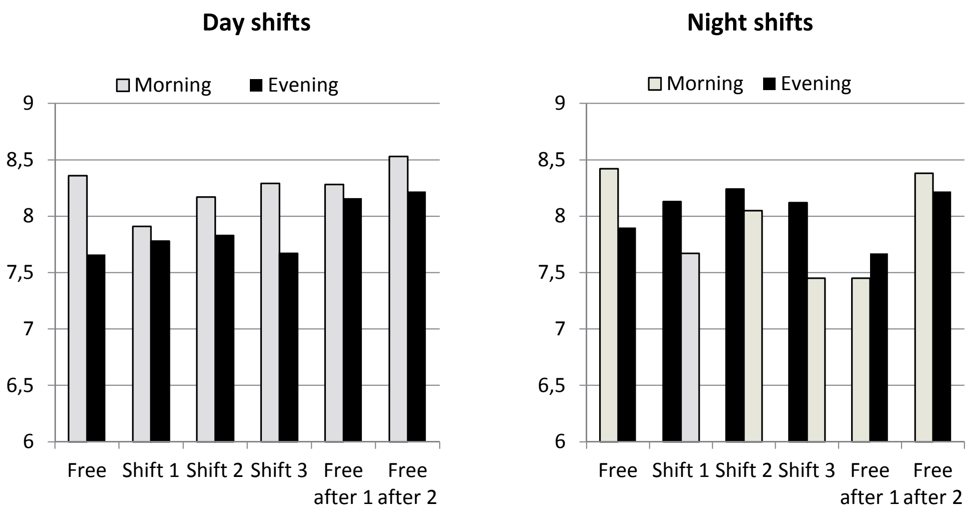


Table 5.1 Descriptive statistics for well-being (1 – 10) before, during and after a series of day and night shifts.

	Well-being							
	Day shifts				Night shifts			
	Start		End		Start		End	
	N	*M (SD)*	N	*M (SD)*	N	*M(SD)*	N	*M(SD)*
Free	23	8.36 (0.87)	23	7.66 (0.94)	23	8.42 (0.85)	23	7.90 (1.02)
Shift 1	23	7.91 (1.02)	23	7.78 (0.76)	23	8.13 (1.06)	23	7.67 (1.08)
Shift 2	23	8.17 (0.76)	23	7.83 (1.31)	22	8.23 (0.91)	22	8.05 (0.90)
Shift 3	23	8.29 (0.68)	23	7.67 (0.88)	22	8.12 (0.84)	22	7.45 (1.28)
Free after 1	23	8.28 (0.85)	23	8.16 (0.89)	11	7.45 (1.04)	23	7.67 (1.16)
Free after 2	22	8.53 (0.74)	23	8.22 (0.78)	23	8.38 (0.83)	23	8.22 (0.98)

Table 5.2 Descriptive statistics for work characteristics during three consecutive day and night shifts.

	On job sleep quality		No of flight missions		Workload		Distressing shifts	
	N	*M (SD)*	N	*M(SD)*	N	*M (SD)*	N	*M (SD)*
Day shifts								
Shift 1			23	2.39 (1.64)	23	4.91 (2.70)	23	2.74 (1.96)
Shift 2			23	2.74 (1.60)	23	5.04 (2.55)	23	3.09 (2.61)
Shift 3			23	2.83 (1.64)	23	4.74 (2.49)	23	2.83 (1.77)
Night shifts								
Shift 1	22	6.55 (1.18)	23	1.04 (0.98)	23	3.96 (2.03)	23	1.74 (0.92)
Shift 2	22	6.23 (1.51)	22	0.86 (0.94)	22	3.41 (2.26)	22	1.64 (1.14)
Shift 3	22	5.86 (1.96)	22	0.86 (0.99)	22	4.00 (2.43)	22	2.50 (1.68)

Table 5.3 Crude correlations between well-being, number of flight missions, workload and distressing shifts during *day* shifts.

		1.	2.	3.	4.	5.
1.	Well-being start shift	-				
2.	Well-being end shift	0.80*	-			
3.	No of flight missions	-0.05	0.15	-		
4.	Workload	-0.57*	-0.46*	0.39	-	
5.	Distressing shifts	-0.04	-0.12	-0.06	0.44*	-

Note: *$p < .05$

Table 5.4 Crude correlations between well-being, number of flight missions, workload and distressing shifts during *night* shifts.

		1.	2.	3.	4.	5.	6.
1.	Well-being start shift	-					
2.	Well-being end shift	0.63*	-				
3.	On job sleep quality	0.00	0.33	-			
4.	No of flight missions	-0.13	-0.41	0.10	-		
5.	Workload	-0.20	-0.53*	-0.03	0.70*	-	
6.	Distressing shifts	-0.25	-0.43*	-0.09	0.46*	0.35	-

Note: *$p < .05$

Test of study hypotheses

Well-being at the start of a series of shifts (Hypothesis 1). RM-ANOVA revealed a significant interaction effect ($F(1, 22) = 5.19$, $p = 0.033$): the change in well-being from a free day before a series of shifts to the start of a series of shifts, differed between day and night shifts. Paired t-test showed that levels of well-being were lower at the start of a series of day shifts (M = 7.91) when compared with levels of well-being at a free morning before a series of day shifts (M = 8.36; $t(22) = 1.88$, $p = 0.037$). Levels of well-being at the start of a series of night shifts (M = 8.13) did not differ significantly from levels of well-being at a free evening before a series of night shifts (M = 7.90; $t(22) = -1.19$, $p = 0.13$). Our first hypothesis received support.

Decrease in well-being during a shift (Hypothesis 2a & 2b). There was no significant decrease in well-being during the first day shift (Start M = 7.91, End M = 7.78, t(22) = 0.19) or the second day shift (Start M = 8.17, End M = 7.83, $t(22) = 1.49$, $p = 0.08$). There was a significant decrease in well-being during the third day shift (Start M = 8.29, End M = 7.67, $t(22) = 4.00$, $p < 0.001$). Post-hoc analysis revealed that the significant decrease in well-being during the third day shift is more attributable to the relatively high score of well-being at the start of the shift than to a low level of well-being at the end of the shift. The level of well-being at the start of the third day shift was significantly higher ($t(22) = -1.95$, $p = 0.032$) than the level of well-being at the start of the first day shift whereas the level of well-being at the end of the first day shift did not differ from that at the end of the third day shift ($t(22) = 0.57$, $p = 0.29$). During all night shifts, levels of well-being significantly decreased (First night shift: Start M = 8.13, End M = 7.67, $t(22) = 1.71$, $p = 0.05$; Second night shift: Start M = 8.22, End M = 8.00, $t(20) = 1.92$, $p = 0.034$; Third night shift: Start M = 8.10, End M =7.44, $t(20) = 2.55$, $p = 0.01$). Hypothesis 2a was thus supported for night shifts. It was partly supported for day shifts, as only during the third day shift participants showed a significant decrease in well-being.

Paired t-tests were used to examine Hypothesis 2b. The non-significant decrease in well-being during the first day shift (M = -0.13) did not differ from the significant decrease in well-being during the first night shift (M = -0.46, $t(22) = 1.25$, $p = 0.12$), just as the non-significant decrease in well-being during the second day shift (M = -0.34) did not differ from the significant decrease in well-being during the second night shift (M = -0.21, $t(20) = -0.44$, $p = 0.33$). Also, the significant decrease in well-being during the third day shift (*M* = -0.59) did not differ from the significant decrease in well-being during the third night shift (*M* = -0.66, $t(20) = .22$, $p = 0.42$). Hypothesis 2b was not supported because the decrease in well-being during day shifts did not differ from the decrease in well-being during night shifts.

Work stressors and well-being (Hypothesis 3). Table 5.5 shows the estimates of the multilevel models for both day and night shifts with well-being at the end of a shift as dependent variable, well-being at the start of the shift, number of flight missions and sleep quality (only for night shifts) as covariates, and workload and distress during shifts as predictors. Model A shows that during day shifts, workload was significantly associated with a decrease in well-being ($b = -0.50$, $p < 0.05$). During night shifts, workload ($b = -0.27$, $p < 0.05$) and distress during shifts ($b = -0.23$, $p < 0.05$) were significantly related to a decrease in well-being. Model B shows that model fit did not decline when the estimates of workload for day and night shifts were considered to be the same ($\chi^2(1) = 1.83$, $p = 0.18$). This suggests that the effects of workload on decrease in well-being during day and night shifts were comparable. Model C shows that model fit did significantly decline when the estimates for distress during shifts during day and night shifts were considered to be the same ($\chi^2(1) = 3.99$, $p = 0.046$). This result, combined with the finding that distress during shifts was significantly related to lower levels of well-being only during night shifts and not during day shifts, suggests that the effect of distress during shifts on the decrease in well-being is stronger during night shifts than during day shifts. Thus, hypothesis 3 did not receive support for workload but was supported for distress during shifts.

Table 5.5 Multivariate model with estimates of the decrease in well-being during day and night shifts; with well-being start shift, number of flight missions and on job sleep quality (only during night shifts) as covariates; and workload and distressing shifts as predictors.

	Model A		Model B		Model C	
	Day shift *b* (SE *b*)	Night shift *b* (SE *b*)	Day shift *b* (SE *b*)	Night shift *b* (SE *b*)	Day shift *b* (SE *b*)	Night shift *b* (SE *b*)
Fixed effects						
Covariates						
Intercept	0.00 (0.10)	-0.01 (0.07)	0.00 (0.09)	-0.01 (0.07)	0.00 (0.10)	-0.01 (0.07)
Well-being start shift	0.46 (0.09)*	0.60 (0.07)*	0.50 (0.09)*	0.62 (0.07)*	0.44 (0.10)*	0.64 (0.07)*
No of flight missions	0.28 (0.11)*	0.13 (0.10)	0.20 (0.10)	0.16 (0.09)	0.29 (0.11)*	0.07 (0.09)
On job sleep quality		0.29 (0.07)*		0.27 (0.07)*		0.28 (0.07)*
Predictors						
Workload	-0.50 (0.11)*	-0.27 (0.09)*	-0.34 (0.07)*	-0.34 (0.07)*	-0.44 (0.12)*	-0.30 (0.08)*
Distressing shifts	0.05 (0.09)	-0.23 (0.09)*	0.01 (0.09)	-0.21 (0.08)*	-0.11 (0.06)	-0.11 (0.06)
Fit statistics						
-2 log (likelihood)	265.05		266.87		269.04	

Note: *$p < .05$

Chapter 5

Recovery time (Hypothesis 4). It took HEMS pilots more hours to recover after a series of night shifts (*M* =19.83, *SD* =10.62) than after a series of day shifts (*M* =15.13, *SD* =8.26, $t(22)$ = -1.99, p = 0.030). Accordingly hypothesis 4 was supported.

DISCUSSION

This study's aim was to examine the effect of a compressed working week with high cognitive and emotional work demands in relation to well-being and recovery within the population of HEMS pilots. Not only is research examining well-being and recovery among HEMS pilots rare, this study also adds to the understanding of the effects of compressed work weeks and demanding work characteristics on well-being and recovery.

In support of our first hypothesis, results revealed that the start of a series of day shifts was more taxing for well-being than the start of a series of night shifts. This finding is in line with earlier research showing that advancing, instead of delaying the body's timing system, is associated with more health complaints (Waterhouse et al., 1997). It also suggests that HEMS personnel could be more fatigued and at risk for accidents at the early start of their day shifts. A reason that employees feel fatigued at a very early-in-the-morning start of the workday is that they sleep less hours in the preceding night (Åkerstedt et al., 2010). Advancing the bedtime in order to sleep 8 h anyway, does not guarantee a good night sleep because most people cannot sleep when they go to bed earlier. The few hours prior to the onset of the nocturnal sleep period has even been referred to as the 'forbidden zone' for sleep (Lavie, 1986). During this time period, sleep propensity is markedly reduced due to a wake-promoting signal generated by the endogenous circadian pacemaker (Fuller et al., 2006). An alternative approach could be to postpone the start of the day shifts. Delaying the start of a workday has a strong impact on sleep length, with 70% of the extra time used for sleep (Ingre et al., 2008). However, delaying the start of the day shifts also implies that the end of the night shifts needs to be delayed which might increase levels of fatigue at the end of the night shifts. Against this background, it could be considered to start day shifts somewhat (but not much) later, for example at 7.00 AM instead of at 6.30 AM. It cannot be recommended to start day shifts earlier than 6.30 AM.

Our second hypothesis was partly supported. HEMS employees did report a significant decrease in well-being during their night shifts and during the third day shift. This finding, combined with findings from earlier shift research (Folkard, 1997; Smith et al., 1998; Rosa, 1995), suggests that, especially during night shifts, HEMS employees could be more fatigued at the end of a shift which could reduce performance and increase the risk of accidents. The decrease in well-being during the third day shift is mainly attributable to the relatively high well-being score at the start of that shift. Possibly this increase in well-being could be due to the adaptation of the body's timing system to the earlier wake times which made it easier for HEMS employees to go to sleep and get up early. Although night shifts did cause a significant decrease in well-being during all three shifts, the decrease in well-being was not significantly higher than during day shifts. This finding is not in line with previous research that consistently showed the higher burden of night shifts when compared to day shifts (Costa, 1996). An explanation for this paradox could be the opportunity of HEMS pilots to sleep during night shifts when they are not called-upon. Power naps during night shifts have been shown to partially off-set the negative effects of night work (Tucker, 2003). Even though the decrease in well-being during shifts did not differ between day and night shifts, after-effects did differ. The results with respect to our fourth hypothesis showed that it took HEMS pilots a longer time to recover from a series of night shifts than from a series of day shifts. As Effort-Recovery theory posits that health is at risk when recovery is slow and incomplete (Meijman & Mulder, 1998), it is possible that in the long run this longer recovery time caused by demanding night work is a risk factor for ill health.

In line with our expectations and previous research (Zohar et al., 2003), distress during shifts was more strongly related to a decrease in well-being during night shifts than during day shifts, even though levels of distress during night shifts were actually lower than during day shifts (see Table 5.2). Other occupations such as nurses or police officers face emotional demands during the night as well. These results suggest that these nightly emotional demands might cause a higher burden for them too. Future research could examine whether these results apply to other service sector occupations as well, and how such differential effects on well-being during day and night shifts emerge.

HEMS pilots reported low levels of distress during their shifts even though they are regularly confronted with emotionally demanding situations such as driving accidents (Blau et al., 2012). It is possible that their demanding work causes a selection for more resilient or hardy persons (Semmer, 2003), in other words, contribute to a healthy worker effect (Shah, 2009). It is also possible that HEMS employees learned to cope with emotional situations, for instance, by withdrawing from the trauma scene as they themselves do not need to give medical assistance. Future research could examine whether such person characteristics or behaviors are related to these low levels of distress.

Strengths and limitations

A strength of this study is that our sample covered almost the entire population of HEMS pilots in the Netherlands. Nearly all HEMS employees agreed to participate and there was no attrition: none of the participants dropped out during the study. In addition, the response rate was about complete with 99% completed questionnaires. This low level of attrition is probably due to the proper introduction of the study, and also to the short and user-friendly questionnaires that we designed with unambiguous and straight-forward items to measure our constructs. The limited selection bias and the absence of attrition support the validity of our results. Another strength is that we also measured well-being during free time. Effort-recovery research presupposes adequate data collection during work, as well as before and after work, and we did not restrict the measures of well-being to the series of shifts. Finally, our data collection period covered a substantial part of the year. This makes it unlikely that our results were influenced by specific holidays or weather conditions.

Research in applied psychology is challenging and complex, because researchers have limited control over the research conditions in natural settings (Griffiths, 1999), and we too had to make some concessions in designing our study. To minimize the interference with daily and nightly working life we limited our measurement method to self-reports. Data triangulation, for example, the combination of self-reports with biological measures of stress or valid measures of performance, for example, standardized tests of executive functioning, would be a means to further improve the knowledge about the effects of shift work. Another limitation is that, in our measure of distress during shifts, we did not disentangle the 'objective' and 'subjective' experience of distress during the shifts (see also Kompier, 2005). Because we asked participants to report their subjective experience of distress during the shifts, we cannot conclude to what extent the actual distressing events affected well-being, or whether also other factors were involved influencing the perception of distress such as job satisfaction. We also could not fully counterbalance the sequences of the series of day and night shifts. Nine pilots completed their measurements starting with a series of night shifts followed by a series of day shifts, whereas 14 pilots started with a series of day shifts followed by a series of night shifts. However, it is unlikely that the sequences of shifts have influenced our results because there was at least three free days between the series of shifts, making it improbable that there were spillover-effects from one series of shifts to another. A last limitation is that our cut off point ($>M$ - 0.5 SD) for considering pilots to be recovered was somewhat arbitrary. However, when a stricter cut off point was used in a sensitivity analysis ($>M$ - 0.25 SD), the results remained the same. It still took pilots a longer time to recover from night shifts than from day shifts (Day shifts: M =17.22, SD =10.12; Night shifts: M =22.24, SD =13.20; $t(22) = -1.80$, $p = 0.044$).

Conclusion

This study was one of the first to examine the effects of a compressed working week with high cognitive and emotional demands in relation to recovery and well-being among HEMS pilots. Their relatively high levels of well-being suggest that they feel competent to do their job even in the face of demanding work characteristics. Although general levels of well-being were high, day and night shifts had differential effects on well-being. When compared to a free morning, well-being was lower at the start of the series of day shifts, possibly due to sleep deficit. In general, compressed work weeks with demanding work characteristics caused the highest burden during the night. Each night shift caused a significant decrease in well-being, subjective sleep quality decreased during the series of night shifts and it took a longer time to recover from a series of night shifts. In addition, distressing shifts caused a higher decrease in well-being during night shifts than during day shifts. It is concluded that from an occupational health and performance perspective, it would not be warranted for HEMS employees to start earlier during day shifts, or to have longer series of night shifts. It is also important to guarantee enough recovery time after a series of night shifts.

Conflicts of interest

There were no conflicts of interest.

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General discussion

INTRODUCTION

Recovery from stress is essential to uphold health and well-being (Meijman & Mulder, 1998). Even though recovery from stress is seen as an important link between psychophysiological responses to job stressors and employee health (Geurts & Sonnentag, 2006), relatively few studies have examined the mechanisms associated with psychophysiological recovery after stress exposure (Sonnentag & Fritz, 2007). The aim of this thesis was to examine the conditions that impede and facilitate recovery after stress exposure and to increase the knowledge about the process of stress recovery. We used experimental and longitudinal field designs with subjective and objective recovery measurements to examine 1) the association between perseverative cognition and (a) physiological recovery from stress and (b) sleep quality (*Research Question 1*); 2) to examine the association between positive and negative affect and physiological recovery from stress (*Research Question 2*); and 3) to examine how recovery from stress unfolds during and after a period of demanding shift work (*Research Question 3*).

In this final chapter, main findings will be summarized and theoretical considerations and suggestions for future research will be discussed (§6.2). The strengths and limitations of this thesis will be addressed (§6.3) as well as the practical implications of this research (§6.4). The last part of this chapter presents a final conclusion (§6.5).

SUMMARY OF MAIN FINDINGS, THEORETICAL CONSIDERATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Perseverative cognition

It is a unique human ability to think about things that have happened in the past or that may occur in the future. These thoughts may be pleasant when remembering the good times or fantasising about a bright and happy future, but may be troublesome when we worry about the bad things that might happen to us or when we ruminate about past stressful events. The perseverative cognition hypothesis argues that the repeated or chronic activation of the cognitive representation of psychological stressors, keeps the stressors ‘alive’ and thereby the individual in a prolonged or reactivated state of psychophysiological arousal which impedes recovery after stress exposure (Brosschot et al., 2006). Two studies were conducted to examine whether perseverative cognition impedes physiological recovery after exposure to a stressful task (*Research Question 1a*) and sleep quality (*Research Question 1b*). An experimental study among undergraduates showed that rumination about the stress task is related to delayed systolic and diastolic blood pressure recovery (*Chapter 2*). The longitudinal field study among Helicopter Emergency Medical Service (HEMS) pilots revealed that perseverative cognition is associated with delayed sleep onset (*Chapter 4*). These results consistently show that perseverative cognition impedes recovery after stress exposure and thereby provide further support for the perseverative cognition hypothesis (Brosschot et al., 2006).

This hypothesis does not make a distinction between levels of perseverative cognition (i.e. intensity and frequency) and the impact of perseverative cognition on recovery from stress. It could be possible that some negative thoughts impede recovery from stress to a stronger degree than others. For instance, rumination and worry might have different effects on recovery from stress.

Rumination has been defined as: “A class of conscious thoughts that revolve around a common instrumental theme and that reoccur in the absence of immediate environmental demands requiring the thoughts” (Martin & Tesser, 1996, p. 7). Rumination is considered to be stronger past-oriented than worrying. Worry, as described by Borkovec et al. (1983, p. 10), is “a chain of thoughts and images, negatively affect-laden and relatively uncontrollable; it represents an attempt to engage in mental problem-solving on an issue whose outcome is uncertain but contains the possibility of one or more negative outcomes”. Worry is thus directed at the future and at problem-solving (Papageorgiou & Wells, 2004). Worry could have a higher impact on cardiovascular recovery from stress than rumination because worrying is related to fear which induces stronger physiological arousal than regret or sadness associated with ruminating about the past (Pieper, 2008). Furthermore, worrying is associated with problem solving and this has also been proven to induce physiological arousal (Verkuil et al., 2009). In line with this reasoning, previous research has shown that worries about the future have a higher impact on heart rate than negative thoughts about the past (Pieper et al., 2007).

The distinction between worry and rumination is also important in research examining the association between perseverative cognition and sleep. A number of studies have shown that rumination and worry are associated with poor sleep quality (e.g. Cropley et al, 2006; Kompier et al., 2012; Selmer & Harvey, 2004). However, research examining the similarities, differences and interactions between worry and rumination in sleep is scarce (Takano et al., 2012). The interaction between rumination and worry might be especially relevant in sleep research. In a prospective study among undergraduates, rumination predicted a significant reduction in sleep quality at a 3-week follow-up while worry was not associated with sleep disturbances three weeks later. However, the main effect of rumination was qualified by its interaction with worry: only among participants with high levels of worry, rumination was a significant predictor of poor sleep quality. In other words, ruminators could be caught up in thoughts about their sleep problems in the past and these thoughts might induce worry about the negative consequences of their sleep problems in the future (Takano et al., 2012).

Irrespective of the question whether some stressor-related thoughts have a higher impact on recovery from stress than others, the question still remains why some people worry or ruminate more about work stressors than others. Previous research has shown that employees who found it difficult to unwind from work (i.e. high trait ruminators) have different core beliefs about work compared to employees who found it easy to unwind from work (i.e. low trait ruminators) (Cropley & Millward Purvis, 2009). High trait ruminators perceived blurred boundaries between work and home life, work was central to their identity and working hard and working long hours were part of their core beliefs, whereas low trait ruminators viewed their work and private lives as different domains. Even though high trait ruminators accepted their work habits, they also reported that they were unable to escape from work. Low trait ruminators felt in control of their work and leisure time, and actively refrained from thinking about work-related issues when not being at work (Cropley & Millward Purvis, 2009). These results suggest that core beliefs about work are related to the ability to switch off from work. Future research could examine whether changing ones' core beliefs about work would result in lower levels of perseverative cognition during leisure time, and consequently a more complete recovery process during off-job time.

Affect

Negative affect. Our studies have shown that negative affect impedes blood pressure recovery (*Research Question 2*). After exposure to a stressful task, participants who watched a movie scene with a negative emotional valence showed slower systolic blood pressure recovery than participants who watched a movie scene with either a neutral or a positive valence or who sat in silence (*Chapter 2*). One might argue that the negative affect manipulation is a stressor in itself, causing cardiovascular activation and thereby impeding the recovery process. However, the pilot study that we performed in advance of this experimental study revealed that the negative movie scene in itself did not induce cardiovascular activation or different levels of cardiovascular activation when compared to the movie scenes with a positive or a neutral valence. Taken together, these findings suggest that negative affect slows down cardiovascular recovery from stress even though it does not cause cardiac activation. These findings raise the question of how exactly negative affect impedes cardiovascular recovery from stress.

Brosschot and Thayer (2003) argue that negative affect impedes cardiovascular recovery from stress because it implies the continuation of unresolved problems or an uncontrollable threatening situation which leads to prolonged rumination. However, our finding that participants in the negative affect condition did not report higher levels of rumination than participants in any of the other conditions does not support this line of reasoning. It could be possible that cognitive processes that occur without our awareness are responsible for the prolonged activation caused by negative affect. Nowadays, it is widely recognized that cognitive processes are often automatic and unconscious (Bargh & Morsella, 2008; Dijksterhuis & Nordgren, 2006). For instance, research has shown that 'unconscious thinking' can solve complex problems better than conscious thinking (Dijksterhuis et al., 2006), and that failed or unfinished tasks that are personally relevant increase unconscious thinking (Rothermund, 2003).

The recognition of unconscious and automatic cognitive processes has inspired researchers to acknowledge the importance of these processes in recovery from stress. Brosschot et al (2010) argue that unconscious perseverative cognition, that is, "the ongoing activated cognitive representation of one or more psychological stressors that occurs while conscious attention is directed elsewhere" (Brosschot et al., 2010, p. 411), constitutes an important factor in recovery from stress (Brosschot et al., 2010). To be more precise, the now 'extended perseverative cognition hypothesis' states that both conscious and unconscious perseverative cognition keep the stressors 'alive', and thereby put the individual in a prolonged or reactivated state of psychophysiological arousal which impedes recovery from stress (Brosschot et al., 2010). That unconscious processes are associated with physiological arousal has been demonstrated in sleep research. Worry during the day increased autonomic activation during nocturnal sleep (Brosschot et al., 2007; Weise et al., 2013), and anticipated stressors after a night of sleep prolonged autonomic activity during the preceding sleep (Hall et al., 2004). During sleep there are obviously no conscious stressor-related thoughts about stressors and thus unconscious processes must be held responsible for increased autonomic activity.

An important issue for future research is the development of a valid and widely recognized measure of unconscious perseverative cognition. A potentially useful candidate to measure unconscious perseverative cognition could follow the principle of 'automatic vigilance'. This is the increased cognitive sensibility for information related to a current goal or task which is stronger after failure, frustration and unfinished tasks (Rothermund, 2003). Lexical decision tasks have been used to measure the principle of automatic vigilance (Neely, 1991). During this task participants have to indicate as fast and accurately as possible whether a string of letters is a word or non-word. A greater accessibility of a construct is measured by faster lexical decision making on semantic associates of that construct (Neely, 1991). If future research would show that the lexical decision task is a reliable and valid method to measure unconscious perseverative cognition, it will become possible to examine whether unconscious perseverative cognition delays recovery from stress as assumed by the extended perseverative cognition hypothesis (Brosschot et al., 2010).

Positive affect. Two experiments were conducted to answer the question of how the experience of positive affect is related to cardiovascular recovery after exposure to a stressful task (*Research Question 2*). Our first attempt to induce positive affect failed because participants who watched a movie scene with a positive valence did not report higher levels of positive affect than participants who watched a movie scene with a neutral valence or who sat in silence (*Chapter 2*). Therefore, we followed a different approach. We asked participants to list their favorite songs that made them feel relaxed ('relaxing music') or that made them feel happy ('happy music'). After having conducted a stressful task, participants listened to either relaxing music or happy music. Results revealed that listening to relaxing or happy music significantly improved mood, and slowed down systolic blood pressure recovery when compared to listening to an audiobook or sitting in silence (*Chapter 3*). This means that the experience of positive affect is not by definition beneficial for cardiovascular recovery from stress.

A possible explanation for this finding is that the manipulation of positive affect (i.e. listening to self-chosen music) elicited physiological arousal. There are quite a number of laboratory studies that examined the cardiovascular response elicited by positive affect. These studies have shown that an active positive affect manipulation, such as the use of personally relevant stimuli, increases heart rate and blood pressure when compared with baseline or a mood-neutral control (e.g. Ekman et al., 1983; Neumann & Waldstein, 2001). In our study, participants listened to music they preferred, in other words, we used personally relevant stimuli to induce positive affect. This might have caused an increase in physiological activation which interfered with cardiovascular recovery from stress. The finding that listening to preferred music increases physiological activation supports this argument (Rickard, 2004; Salimpoor et al., 2009).

One might argue that the experience of positive affect still benefits cardiovascular recovery from stress but only when it does not elicit physiological activation. Studies that did *not* show the increase in physiological activation caused by positive affect typically entailed passive inductions of positive affect such as movie scenes (Christie & Friedman, 2004; Fredrickson et al., 2000). However, as shown in Chapter 2, these passive inductions of positive affect might not significantly increase levels of positive affect. More personally relevant stimuli might significantly increase levels of positive affect but at the same time might also induce physiological activation (e.g., Ekman et al., 1983; Neumann & Waldstein, 2001). Considering these findings, it could be a challenge to significantly increase levels of positive affect without eliciting physiological activation. At least, we can conclude that the 'undoing hypothesis of positive emotions' is too restrictive when it claims: "perhaps positive emotions themselves do not generate cardiovascular reactivity, but instead quell any existing cardiovascular reactivity caused by negative emotions" (Fredrickson et al., 2010, p. 240).

An interesting question for future research would be whether positive affect facilitated cardiovascular recovery from stress when positive affect is not dependent on exposure to positive stimuli. In other words, people that experience high levels of trait positive affect might show faster cardiovascular recovery from stress. Research has shown that trait positive affect was associated with beneficial health behavior such as better sleep quality (Fosse et al., 2002), better problem solving skills (Ashby et al., 1999; Dreisbach & Goschke, 2004) and adaptive coping strategies (Folkman & Moskowitz, 2000; Tugade et al., 2004). These beneficial health behaviors might as well facilitate physiological recovery from stress. To our knowledge there is only one study examining this hypothesis, and indeed results showed that higher levels of trait positive affect were associated with more complete cardiovascular and subjective recovery from stress (Papousek et al., 2010).

Demanding shift work

This thesis also examined the question of how recovery unfolds during and after a period of demanding shift work (*Research Question 3*). A longitudinal field study among HEMS pilots revealed that night shifts were in general more demanding than day shifts. Distress during night shifts was more strongly related to a decrease in well-being than during day shifts, each night shift caused a significant decrease in well-being, and night shifts were associated with a longer recovery time than day shifts were. Only the start of a series of day shifts was more demanding than the start of series of night shifts (*Chapter 5*).

The finding that distress was more strongly related to a decrease in well-being during night shifts than during day shifts suggests that emotional job demands during night shifts amplify the negative effects of shift work. To cope with emotional job demands and buffer the negative effects of these demands on well-being it is important for HEMS pilots to have access to job resources. Job resources are the physical, psychological, social or organizational aspects of the job that are functional in achieving work goals and reducing job demands (de Jonge & Dormann, 2003; Demerouti et al., 2003). According to the Job-Demands Resources model (JD-R model: Demerouti et al., 2001) and the Demand-Induced Strain Compensation model (DISC model: de Jonge & Dormann, 2003), job resources such as job control and social support are beneficial for health when coping with job demands. The DISC model proposes that emotional resources are most important in coping with emotional job demands such as distress (de Jonge & Dormann, 2003). Indeed, research among health care workers has shown that emotional resources such as support from supervisors and colleagues buffer the negative effects of emotional job demands such as confrontations with death, illness and suffering (de Jonge et al., 2006; 2008). These results suggest that emotional resources such as support from a colleague might be beneficial for HEMS pilots to cope with distress. It is likely that those emotional resources are less available to HEMS pilots during night shifts than during day shifts because colleagues might be asleep. Therefore, future research should not only examine if emotional resources buffer the negative effects of distressing shifts but also whether these emotional resources differ in availability during day and night shifts.

Research Question:	Answers:	Future research should:
1 How does perseverative cognition influence a) physiological recovery from stress and b) sleep quality?	• Perseverative cognition delays blood pressure recovery from stress • Perseverative cognition delays sleep onset	• Examine the distinction between level and impact of perseverative cognition • Examine why some people are more pre-occupied with work than others
2 How does the experience of negative and positive affect influence physiological recovery from stress?	• Negative affect delays blood pressure recovery from stress • Positive affect does not necessarily speed up cardiovascular recovery from stress	• Examine how negative affect delays blood pressure recovery • Examine whether trait positive affect facilitates recovery from stress
3 How does recovery from stress unfold during and after a period of demanding shift work?	• The start of a series of day shifts is more demanding than the start of a series of night shifts • There were no differences in the decrease in well-being during day and night shifts • Distress during night shifts was more strongly related to a decrease in well-being than during day shifts • It takes a longer time to recover from a series of night shifts than from a series of day shifts	• Examine whether emotional resources can benefit HEMS pilots to deal with distressing shifts • Examine the availability of emotional resources during day and night shifts

STRENGTHS AND LIMITATIONS

Strengths

A main strength of this thesis is the use of strong methodological designs to examine the process of recovery from stress. We believe that this thesis adds substantially to the knowledge of the process of recovery from stress by using (i) longitudinal designs, (ii) with subjective and objective recovery measures, (iii) in both experimental and applied settings

Longitudinal designs. The use of longitudinal designs permits stronger conclusions about causality than cross-sectionals designs because the temporal order of the variables can be determined unambiguously (Taris & Kompier, 2003). The longitudinal designs also made it possible to examine the process of recovery in detail: we were able to examine the change over time in the effect of the causal variables on stress recovery. It is also important to note that there was almost no attrition in our research. This means that selection bias, a potential negative characteristic of longitudinal designs, does not apply to our results (Taris, 2000).

Experimental and applied settings. We examined the process of stress recovery using experimental and applied designs and combined the strengths of both designs in this thesis. Adequate experimental designs are well-controlled which makes it less likely that other than the independent variables affect the outcome measure. Applied designs often have high ecological validity because the methods, materials and setting better approximate the 'real-world'. We believe that the combination of experimental and applied research designs positively impacts the validity of this thesis' results.

Subjective and objective measures. Another strong point in our methodology is that we consider the utilization of both 'objective' and 'subjective' measures. The use of objective measures made it less likely that our results suffer from a retrospective bias or biases due to respondent's response styles (Kompier, 2005).

Limitations

Even though we used a powerful approach to examine the process of recovery from stress, the studies described in this thesis are not without limitations. These limitations are already discussed in detail in the previous chapters. Here we will discuss the three general limitations of this thesis: (i) the composition of the samples, (ii) the validity of the used measurements, and (iii) the possibility of reversed causation.

Composition of samples. The samples in our studies consisted of undergraduates and HEMS pilots. Both samples are highly educated and the working conditions of the pilots are very specific. This specific composition of our samples could be considered a limitation, because it raises the question to what extent our results can be generalized to other populations with lower education levels or different working conditions. However, it does not seem likely that the rather fundamental processes that are examined in this thesis will operate differently in other samples.

Validity of measurements. The self-report measures used in this thesis were specifically constructed for our studies and mostly constitute of one-item measures. The use of one-item measures that were not previously validated could be considered a limitation of this thesis. However, because we aimed to repeatedly measure the same constructs, measurements had to be short, unobtrusive and user-friendly. Therefore, we constructed one-dimensional and unambiguous one-item measures for our studies. In previous work of our group, these have been shown to be a legitimate and very adequate alternative for multiple-item measures (Van Hooff et al., 2007).

Reversed causation. In this thesis we examined in a field setting the associations between work stressors and sleep quality (*Chapter 4*), and between work stressors and well-being (*Chapter 5*) without examining the possibility of reversed causation. As a consequence, we cannot exclude the possibility that poor sleep quality and low levels of well-being influence the objective or perceived work environment. It is possible that lack of sleep and low levels of well-being intensify the consequences of work stressors (Zohar et al., 2003), or cause pilots to make more mistakes and receive criticism and less social support (Spector et al., 2000). Moreover, the perceptions of workload and distress could be influenced by a lack of sleep and low levels of well-being (De Lange et al., 2004; Taris & Kompier, 2014). Still, even though sleep quality or well-being could influence the objective work stressors or the experience thereof, this does not refute our finding that work stressors are related to well-being and sleep quality.

Strengths	Limitations
• Repeated measurements	• Highly educated samples
• Well-controlled and ecological valid data	• Use of ‘minimal measures’
• Multi-method: psychological and physiological measures	• Possibility of reversed causation

PRACTICAL IMPLICATIONS

Prevention is better than cure. Therefore, employers should design jobs that are optimal for performance and health. One of the most influential job stress theories that acknowledges the importance of job characteristics in performance and health is the Job Demand-Control model (JDC; Karasek, 1979). The model specifies two major work characteristics that are important in worker health and performance: job demands and job control. Examples of job demands are deadlines, and emotional and cognitive demands, whereas job control refers to the degree of decision latitude or autonomy at the job. According to the JDC model, jobs with high job demands and high levels of control facilitate learning and performance, whereas jobs with high job demands and low levels of control induce stress (Karasek, 1979). To optimize performance and to prevent stress, we advise employers to design jobs with high levels of job control. This implies that employees, within certain limits, can make their own decisions as to work procedures and work planning.

Even jobs that fulfill the criteria of optimal job design cannot always prevent work stress to occur. After a stressful workday, it is important to avoid activities or experiences that cause negative affect and to prevent perseverative cognition. Cardiovascular recovery may well be slower and thinking about work might cause problems to fall asleep. Seeking distraction benefits recovery from stress (Gerin et al., 2006), but practicing this strategy might not be suitable for every situation. It could be hard to distract ourselves when lying in bed and trying to catch some sleep. Other approaches to stop thinking about work during leisure time are changing the beliefs about the usefulness of perseverative cognition (Moulds et al., 2010) or changing the meaning of work in your private life (Cropley & Millward Purvis, 2009). Another beneficial approach might be mindfulness meditation. It encourages the cultivation of nonjudgmental moment-to-moment awareness rather than dwelling on past negative events. Mindfulness has been shown to reduce ruminative thoughts and negative affect (Borders et al., 2010; Jain et al., 2007). Exercise could also benefit recovery from stress. It improves mood (Cooney et al., 2013) and attenuates the cardiovascular response during stress and recovery (Dienstbier, 1989; Sothmann et al., 1996; Spalding et al., 2004).

It took HEMS pilots a longer time to recover after a series of nights shifts than after a series of day shifts. Because health is at risk when recovery is slow and incomplete (Meijman & Mulder, 1998), it is important that HEMS pilots do not have longer series of night shifts and do have enough recovery time after a series of night shifts. Our research also showed that levels of well-being were relatively low at the start of a series of day shifts, probably because HEMs pilots slept less during the night before the start of series of day shifts. It is hard to advance bedtime to guarantee a good night of sleep (Lavie, 1986) and therefore we recommend postponing the start of a series of day shifts. Delaying the start of a workday has a strong positive effect on sleep length (Ingre et al., 2008). When delaying the start of day shifts, it should be taken into account that it will delay the end of night shifts as well. Therefore, it is recommended to start day shifts somewhat later but not too much, for example at 7.00 AM instead of 6.30 AM.

Practical implications

- Stress prevention is better than cure
- Engage in activities that prevent or reduce negative affect and perseverative cognition after a stressful workday
- HEMS pilots should have no more than three consecutive night shifts
- Guarantee enough recovery time after series of nights shifts for HEMS pilots
- Postpone the start of day shifts among HEMS pilots with 30 minutes

CONCLUSION

This thesis' findings add substantially to the knowledge of the process of recovery from stress. By using a strong methodological approach with repeated 'objective' and 'subjective' measures in both experimental and field settings, we were able to examine the psychophysiological processes in recovery from stress and make some causal inferences that are ecologically valid This thesis demonstrates that perseverative cognition and negative affect impede cardiovascular recovery, whereas a positive feeling is no guarantee for fast cardiovascular recovery from stress. The adverse effect of perseverative cognition on stress recovery is substantiated by the finding that it increased the time to fall asleep. Furthermore, this thesis revealed that night shifts were in generally more demanding than day shifts and were associated with a longer recovery time.

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Summary

INTRODUCTION

Over the last decades there have been dramatic changes in the nature and conditions of work. Economic, social and technical developments have increased (inter)national competition, and the necessity of efficiency and high productivity. Not surprisingly, many employees indicate that they experience work stress. Work stress can be defined as the harmful responses that occur when the requirements of the job do not match the capabilities, resources or needs of the worker. It has been associated with feelings of depression, job dissatisfaction, substance abuse, hypertension and cardiovascular diseases.

The Effort-Recovery theory illustrates how work stress can lead to impaired health. This theory suggests that employees invest effort when dealing with work-related demands. This effort investment is associated with psychophysiological load effects, such as fatigue, from which people need to recover. As long as complete recovery occurs, that is, psychophysiological activation returns to baseline levels before effort is required again, health is not at risk. However, when psychophysiological activation is prolonged and does not return to baseline levels, load effects may accumulate over time and may jeopardize the precarious internal equilibrium and cause serious health threats.

To preserve employee health it is therefore important to increase the knowledge about recovery after stress exposure and examine the conditions that facilitate or impede stress recovery. Specifically, the role of perseverative cognition, affect and demanding shift work in the process of recovery from stress will be examined.

Perseverative cognition. The perseverative cognition hypothesis states that negative, repetitive and uncontrollable thoughts about psychosocial stressors keep the stressors 'alive' and prolong or reactivate the physiological arousal associated with the initial stress reaction and impede cardiovascular recovery after stress exposure. Not only is perseverative cognition associated with slower cardiovascular recovery from stress, it also has adverse effects on sleep. Ruminating or worrying about stressors while trying to wind down, induces arousal or prolongs the arousal associated with the initial stressor, and interferes with sleep.

Affect. The way we feel influences how fast we recover from a stressful experience. Negative affect has been suggested to slow down physiological recovery from stress, whereas positive affect has been suggested to facilitate physiological recovery from stress. The beneficial effect of positive emotions in stress recovery can be understood from the perspective of the 'undoing hypothesis of positive emotions'. This theory states that the adaptive value of positive emotions is to restore the internal equilibrium that is disrupted by the physiological activation caused by negative emotions.

Demanding shift work. In modern society, more and more people work during abnormal working hours, and shift work has become more common. Shift work often encompasses work outside the conventional daytime and thereby covers fixed evening and night work. This puts an extra demand on the recovery process because it requires people to be active at times when they would normally be sleeping and vice versa.

AIM OF THIS THESIS

This thesis' aim was to arrive at a better understanding of the process of recovery from stress. We used experimental and field designs with repeated-measures and subjective and objective indicators of recovery in order to examine the following three research questions:

1) How does perseverative cognition influence (a) physiological recovery from stress and (b) sleep quality?
2) How does the experience of negative and positive affect influence physiological recovery from stress?
3) How does recovery from stress unfold during and after a period of demanding shift work?

RESULTS OF THE STUDIES

Perseverative cognition. In *Chapter 2* we examined whether perseverative cognition is related to delayed physiological recovery after exposure to a stressful task. In an experimental study among undergraduates, stress was elicited by exposing participants (N =110) to a mental arithmetic task with emotional harassment. During the experiment, heart rate and blood pressure were measured continuously. Levels of perseverative cognition were measured after the stress task. Multilevel analysis indicated that perseverative cognition was related to delayed systolic and diastolic blood pressure recovery.

Chapter 4 presents the findings of a longitudinal field study among Helicopter Emergency Medical Service (HEMS) pilots. We hypothesized work stress and perseverative cognition to be associated with poor nocturnal sleep quality and the association between work stressors and poor nocturnal sleep quality to be mediated by perseverative cognition. Participants (N = 24) wore actigraphs to assess sleep onset latency, total sleep time and number of awakenings. At the end and at the start of three consecutive day shifts, the HEMS pilots completed questionnaires measuring work stress (workload, distressing shifts and work-related conflicts) and perseverative cognition. Correlation analysis showed that distressing shifts and perseverative cognition were associated with delayed sleep onset latency. A bootstrapping mediation procedure revealed the mediating role of perseverative cognition in the association between distressing shifts and sleep onset latency.

Affect. In *Chapter 2* we examined the question of how the experience of positive and negative affect is related to physiological recovery after exposure to a stressful task. In an experimental study among undergraduates, stress was elicited by exposing participants (N =110) to a mental arithmetic task with emotional harassment. After the stress task, participants were randomly assigned to one of four conditions where they (1) watched a negative movie scene from 'Sophie's Choice', (2) watched a positive movie scene from 'There's Something About Mary', (3) watched a neutral movie scene from 'Planet Earth', or (4) sat in silence. During the entire experiment, heart rate and systolic and diastolic blood pressure levels were measured continuously. Levels of affect were measured after watching the movie scene or sitting in silence. Results revealed that the positive affect manipulation was not effective. Participants who watched a positive movie scene did not report higher levels of positive affect than participants who watched a movie scene with a neutral valence or sat in silence. Participants who watched a negative movie scene reported higher levels of negative affect and showed slower blood pressure recovery.

In *Chapter 3* we tried a different method to increase levels of positive affect. During the first part of the study, participants (N = 123) were asked to list their favorite music that made them feel relaxed or that made them feel happy. During the second part of the study, participants were invited to the laboratory and exposed to a mental arithmetic task with emotional harassment to induce stress. Afterward, participants were randomly assigned to one of four conditions where they (1) listened to self-chosen relaxing music, (2) listened to self-chosen happy music, (3) listened to an audiobook, or (4) sat in silence. The last two conditions were control conditions. During the experiment, blood pressure and heart rate were measured continuously. Positive affect was measured after the stress task and after participants listened to music, an audiobook or sat in silence. The statistical analysis showed that participants who listened to either relaxing or happy music reported higher levels of positive affect and showed slower systolic blood pressure recovery than participants in both control conditions. There were no differences in cardiovascular recovery from stress between participants who listened to either preferred happy music and preferred relaxing music.

Demanding shift work. Chapter 5 presents the findings of a longitudinal field study among Dutch Helicopter Emergency Medical Service (HEMS) pilots. This study examined the effects of demanding shift work on the process of recovery from stress. Work stressors (workload, distressing shifts and work-related conflicts) were measured at the end of each shift and levels of well-being were measured before, during and after a series of three consecutive day or night shifts. Results revealed that night shifts were in general more demanding than day shifts. Distress during night shifts was more strongly related to a decrease in well-being than during day shifts, each night shift caused a significant decrease in well-being, and night shifts were associated with a longer recovery time than day shifts. Only the start of a series of day shifts was more demanding than the start of series of night shifts.

DISCUSSION

Perseverative cognition. In line with the perseverative cognition hypothesis, perseverative cognition was associated with delayed blood pressure recovery, and a longer time to fall asleep. Future research could make a distinction between the level and impact of perseverative cognition on stress recovery and sleep. Some stressor-related thoughts, such as worries, might impact stress recovery to a stronger extent than others. Another important question for future research is why some employees are more pre-occupied with work than others.

Affect. Negative affect was related to slower cardiovascular recovery. However, the question still remains of how negative affect impedes cardiovascular recovery. It is possible that negative affect implies the continuation of unresolved problems or an uncontrollable threatening situation. This might lead to prolonged rumination that impedes cardiovascular recovery from stress. However, we did not find an effect of negative affect on levels of rumination. It could be possible though that cognitive processes that occur without awareness are responsible for the prolonged activation caused by negative affect. Unconscious perseverative cognition, that is, the ongoing cognitive representations of psychological stressors that occur without conscious awareness, could also keep the stressor 'alive' and thereby the individual in a prolonged or reactivated state of physiological arousal. To examine whether unconscious perseverative cognition could delay physiological recovery from stress, future research first needs to develop a valid measure of unconscious perseverative cognition.

In contrast to our expectations, the experience of positive affect was not associated with faster cardiovascular recovery from stress. A possible explanation for this finding is that the manipulation of positive affect that was used, that is, listening to preferred music, elicited physiological arousal and thereby impeded cardiovascular recovery from stress. Future research could examine whether the experience of positive affect facilitates cardiovascular recovery from stress when it is not dependent on exposure to positive stimuli. For instance, trait positive affect is associated with beneficial health behaviors which might facilitate cardiovascular recovery from stress as well.

Demanding shift work. The longitudinal field study among HEMS pilots showed that in general night shifts were more demanding than day shifts. Distress during night shifts was related to a decrease in well-being whereas distress during day shifts was not, each night shift caused a significant decrease in well-being, and night shifts were associated with a longer recovery time than day shifts. The finding that distress was more strongly related to a decrease in well-being during night shifts than during day shifts suggests that emotional job demands during night shifts amplify the negative effects of shift work. Future research could examine whether emotional resources buffer the negative effects of distressing shifts and whether these emotional resources differ in availability during day and night shifts.

Strengths and limitations

The most important strength of this thesis is the use of strong methodological designs to examine the process of recovery from stress. In both experimental and applied settings, 'subjective' and 'objective' indicators of recovery were repeatedly measured. This strong methodological approach contributes to the reliability and validity of our data and gave us the possibility to permit some conclusions about causality.

Even though we used a powerful approach to examine the process of recovery from stress, the studies described in this thesis are not without limitations. The composition of our samples could be considered a limitation. The highly educated samples and the specific working conditions of the pilots raise the question to what extent our results can be generalized to other populations. Another limitation is the validation of the used measurements. We used mostly one item measures that were not extensively validated in previous studies. Another limitation is that we did not examine the possibility of reversed causation. The associations between work stressors and sleep quality, and between work stressors and well-being were examined without examining the possibility that poor sleep quality and low levels of well-being may also influence the degree of work stress.

Practical implications

Prevention is better than cure. Therefore, from a practical perspective it is important that employers design jobs with high levels of control to optimize performance and health. When stress cannot be prevented, employees may well engage in activities that impede negative affect and perseverative cognition to optimize stress recovery. Perseverative cognition during leisure time might be decreased by changing the beliefs about the usefulness of perseverative cognition or changing the meaning of work in private life. Seeking distraction might decrease perseverative cognition as well. Other approaches to improve mood and decrease perseverative cognition are mindfulness meditation and exercise. Both approaches have been shown to decrease negative affect and exercise further attenuates the cardiovascular response during stress and recovery.

It took HEMS pilots a longer time to recover after a series of night shifts than after a series of day shifts. To preserve health it is therefore important that HEMS pilots do not have longer series of night shifts and do have enough recovery time after a series of night shifts. Another recommendation is to postpone the start of a series of day shifts. Our research showed that the start of a series of day shifts was relatively demanding for HEMS pilots. When postponing the start of a series of day shifts, it has to be taken into account that it will delay the end of the night shifts as well. Therefore, it is recommended to start day shifts somewhat later but not too much, for example at 7.00 AM instead of 6.30 AM.

Conclusion

This thesis' findings add substantially to the knowledge of the process of recovery from stress. They demonstrate that perseverative cognition and negative affect impede cardiovascular recovery from stress, whereas a positive feeling is no guarantee for faster cardiovascular recovery from stress. The adverse effect of perseverative cognition on stress recovery is substantiated by the finding that it increased the time to fall asleep. Furthermore, this thesis revealed that night shifts were in generally more demanding than day shifts and were associated with a longer recovery time.

Samenvatting

INLEIDING

Het werk en de werkomstandigheden zijn de laatste jaren sterk veranderd. Economische, technologische en sociale ontwikkelingen hebben niet alleen de aard van het werk veranderd, maar ook de concurrentie versterkt. Bedrijven moeten steeds efficiënter werken om de concurrentie voor te blijven en de werkdruk is toegenomen. Deze hogere werkdruk heeft ertoe geleid dat werknemers steeds vaker aangeven werkstress te ervaren. Werkstress ontstaat wanneer de eisen die het werk stelt hoog zijn en de werknemer het gevoel heeft niet over voldoende mogelijkheden of middelen te beschikken om aan deze hoge werkeisen te voldoen. Deze overbelasting heeft negatieve gevolgen voor de gezondheid. Werkstress wordt in verband gebracht met onder andere depressies, piekeren, angst, een verminderd functioneren van het immuunsysteem en hart- en vaatziekten.

De Inspanning-Herstel theorie geeft een verklaring voor de negatieve gevolgen van werkstress. Deze theorie veronderstelt dat werknemers fysieke en psychologische inspanning leveren om aan de eisen van het werk te voldoen. Werkstress heeft geen negatieve gevolgen voor de gezondheid wanneer de werknemer volledig herstelt van deze inspanningen. Daarentegen kan een negatieve spiraal ontstaan wanneer een werknemer nog steeds gespannen of vermoeid is aan het begin van een nieuwe werkdag. De werknemer is onvoldoende hersteld waardoor extra inspanning moet worden geleverd om aan de eisen van de aankomende werkdag te voldoen. Hierdoor wordt het belang van herstel alleen maar groter, terwijl het meer tijd kost om van de extra geleverde inspanningen te herstellen. Bij herhaaldelijk onvolledig herstel zal de werknemer zich steeds vermoeider en prikkelbaarder gaan voelen. De disbalans tussen inspanning en ontspanning zorgen voor een ontregeling van de fysiologische processen welke betrokken zijn bij lichamelijke inspanning en ontspanning. Deze ontregeling van fysiologische processen zorgt voor het ontstaan van gezondheidsproblemen.

De Inspanning-Herstel theorie geeft weer waarom het belangrijk is om te herstellen van stress, want zonder volledig herstel kunnen ernstige gezondheidsklachten ontstaan. Een grotere mate van kennis over de factoren die van invloed van zijn op het herstel van stress is zeer belangrijk omdat deze kennis kan worden gebruikt om het herstel te bevorderen. In dit proefschrift zal de invloed van persistente gedachten, emoties en veeleisende ploegendiensten op stressherstel worden onderzocht.

Persistente gedachten. Wanneer je een stressvolle situatie meemaakt, kan het voorkomen dat je over deze situatie blijft nadenken. De 'perseverative cognition hypothesis' veronderstelt dat piekeren over een stressvolle situatie ervoor zorgt dat het herstel van stress wordt vertraagd. Omdat het lichaam geen onderscheid maakt tussen een stressvolle situatie die zich die zich in werkelijkheid voordoet en een stresssituatie die zich in gedachten voordoet, zal het in beide gevallen een fysiologische stressreactie vertonen. Dit betekent dat de fysiologische stressreactie wordt geactiveerd wanneer je piekert over een stressvolle situatie uit het verleden of je zorgen maakt over de toekomst, zelfs al zit je veilig thuis op de bank en is er eigenlijk niets aan de hand. Daarnaast kan piekeren ervoor zorgen dat je minder goed slaapt. Dat is onwenselijk aangezien slaap de belangrijkste activiteit is de bijdraagt aan herstel na een stressvolle dag.

Emoties. Hoe snel we herstellen van een stressvolle situatie wordt niet alleen beïnvloed door onze gedachten, maar ook door ons gevoel. Een negatief gevoel wordt verondersteld het herstel van stress te vertragen terwijl een positief gevoel het herstel bevordert. Volgens de 'undoing hypothesis of positive emotions' zijn positieve emoties nuttig, omdat ze de fysiologische activatie die wordt veroorzaakt door negatieve emoties tenietdoen. Hierdoor wordt het herstel van stress bevorderd.

Veeleisende ploegendiensten. Door de 24-uurs economie zijn ploegendiensten steeds normaler geworden en wordt er vaker buiten standaard werktijden gewerkt, zoals 's avonds en 's nachts. Nachtdiensten vereisen dat werknemers actief zijn op momenten waarop ze normaal gesproken zouden slapen en dat ze slapen op momenten waarop zij normaliter wakker zouden zijn. Deze verstoring van het slaap-waakritme leidt tot vermoeidheid, waardoor werknemers extra inspanning moeten leveren om aan de werkeisen te voldoen en het herstel van stress meer tijd kost.

DOEL VAN DIT PROEFSCHRIFT

Dit proefschrift heeft als doel om de kennis te vergroten over de factoren en mechanismen die van invloed zijn op het herstel van stress. In twee experimentele onderzoeken zijn bloeddruk en hartslag gemeten om het fysiologisch herstel van stress in kaart te brengen. Daarnaast is longitudinaal veldonderzoek uitgevoerd waarbij subjectief herstel en objectieve slaapkwaliteit herhaald zijn gemeten. Hierdoor was het mogelijk om het proces van stressherstel in kaart te brengen en de volgende onderzoeksvragen te beantwoorden:

1) Wat is de invloed van persistente gedachten op a) fysiologisch herstel van stress en b) slaapkwaliteit?
2) Wat is de invloed van negatieve en positieve emoties op fysiologisch herstel van stress?
3) Wat is de invloed van een serie veeleisende ploegendiensten op herstel van stresss?

RESULTATEN VAN DE STUDIES

Persistente gedachten. In *Hoofdstuk 2* is de verwachting onderzocht of piekeren het fysiologisch herstel van stress vertraagt. In een experimentele studie werden studenten (N = 110) blootgesteld aan een stressvolle situatie door hen een rekentaak uit te laten voeren waarbij ze van 9000 moesten terugtellen in stappen van 13. Terwijl ze terugtelden kregen de studenten vervelende opmerkingen te horen, zoals "Begin maar weer opnieuw", "Het moet sneller" en

“Probeer je nu echt goed te concentreren”. De mate waarin de deelnemers piekerden over de rekentaak werd vijf minuten na afloop van de rekentaak gemeten. Gedurende het hele experiment werden hartslag en bloeddruk gemeten. De rekentaak zorgde voor een toename in bloeddruk en hartslag. Zoals verwacht verliep het herstel in bloeddruk trager naarmate de studenten meer piekerden over de rekentaak. Het herstel in hartslag werd niet beïnvloed door de mate van piekeren.

Hoofdstuk 4 is de weergave van een longitudinaal veldonderzoek onder traumahelikopterpiloten (N = 24). In deze studie werd onderzocht of werkstress ervoor zorgde dat de piloten minder goed sliepen, doordat ze meer piekerden over een stressvolle werkdag. Gedurende een serie van drie opeenvolgende dagdiensten droegen de traumahelikopterpiloten een bewegingsmeter waarmee de inslaaptijd en de totale slaaptijd kon worden gemeten, maar ook het aantal keer ontwaken per nacht. Aan het begin en aan het einde van de dagdiensten vulden de piloten vragenlijsten in om de mate van werkstress en de mate van piekeren te meten. De resultaten van het onderzoek toonden aan dat werkstress er niet voor zorgt dat de piloten korter sliepen of vaker wakker werden, maar werkstress was wel gerelateerd aan een langere inslaaptijd. Dit verband kon worden verklaard door de mate van piekeren. Op een stressvolle werkdag piekerden de piloten meer, waardoor het moeilijker werd om in slaap te vallen.

Emoties. In *Hoofdstuk 2* is niet alleen de mate van piekeren onderzocht maar ook de invloed van positieve en negatieve gevoelens op fysiologisch herstel van stress. Na de stressvolle rekentaak werden de deelnemers willekeurig in vier verschillende groepen opgedeeld waarbij filmscènes werden gebruikt om de emoties van de deelnemers te beïnvloeden. Sommige deelnemers kregen een (1) positieve scène uit ‘There’s something about Mary’ te zien, anderen kregen een (2) negatieve scène uit ‘Sophie’s Choice’ te zien en weer anderen kregen een (3) neutrale scène uit ‘Planet Earth’ te zien. Daarnaast kreeg een aantal deelnemers geen filmscene te zien en (4) uitsluitend de instructie om zich te ontspannen. Vervolgens werd gemeten in welke mate de deelnemers positieve dan wel negatieve emoties ervaarden. Gedurende het hele experiment werden de hartslag en de bloeddruk gemeten. De resultaten toonden aan dat de deelnemers die de positieve filmscène hadden gezien geen sterkere positieve emoties ervaarden dan de deelnemers die de neutrale filmscène hadden gezien of de instructie hadden gekregen om zich te ontspannen. Overeenkomstig de verwachting ging het kijken van de negatieve filmscène wel gepaard met sterkere negatieve emoties en een trager herstel in bloeddruk dan het kijken van een neutrale filmscène.

In *Hoofdstuk 3* is een opnieuw de relatie onderzocht tussen positieve emoties en fysiologisch herstel van stress. In het eerste deel van het onderzoek werden de deelnemende studenten (N = 132) gevraagd naar enerzijds de artiest en titel van een muzieknummer waarnaar ze het liefst luisterden om te ontspannen en anderzijds de artiest en titel van een muzieknummer waarnaar ze het liefst luisterden om zich vrolijk te voelen. In het tweede deel van het onderzoek werden de deelnemers blootgesteld aan dezelfde stressvolle rekentaak als beschreven in *Hoofdstuk 2*. Vervolgens werden de deelnemers willekeurig in vier groepen ingedeeld en luisterden ze naar

(1) ontspannen muziek, (2) vrolijke muziek, (3) een deel van een luisterboek of (4) luisterden ze nergens naar en kregen ze enkel de instructie om zich te ontspannen. De derde groep was een controlegroep en toegevoegd aan het experiment om te onderzoeken of het luisteren naar muziek een andere invloed heeft op het herstel van stress dan het luisteren naar een verhaal. De vierde groep was ook een controlegroep en toegevoegd om te onderzoeken of het luisteren naar iets, ongeacht of het muziek of een verhaal is, van invloed is op het herstel van stress. Gedurende het hele experiment werden de hartslag en bloeddruk gemeten. De mate waarin de deelnemers positieve emoties ervaarden werd gemeten nadat de deelnemers naar muziek óf het luisterboek hadden geluisterd óf zich enige tijd hadden ontspannen. De resultaten toonden aan dat de deelnemers die naar ontspannen of naar vrolijke muziek hadden geluisterd in sterkere mate positieve emoties ervaarden dan de deelnemers in de controlecondities, maar dat positieve emoties niet gepaard gingen met sneller herstel van stress. In tegenstelling tot de verwachting zorgde het luisteren naar ontspannen en vrolijke muziek juist voor een trager herstel in bloeddruk. Er was geen verschil in herstel in bloeddruk tussen deelnemers die naar ontspannen muziek luisterden of naar vrolijke muziek.

Veeleisende ploegendiensten. In *Hoofdstuk 5* wordt dezelfde longitudinale veldstudie onder traumahelikopterpiloten (N = 24) weergegeven als in *Hoofdstuk 4* maar nu met andere onderzoeksvragen. In dit hoofdstuk werd onderzocht hoe het herstel van stress verloopt tijdens, maar ook na, een aantal ploegendiensten. Gedurende een serie van drie dag- en nachtdiensten werd zowel voor, tijdens als na de serie van diensten het welzijn van de piloten gemeten. Daarnaast rapporteerden de piloten aan het einde van elke dienst in welke mate ze werkdruk ervaarden en in welke mate ze de dienst aangrijpend vonden. De resultaten van dit onderzoek toonden aan dat nachtdiensten veeleisender zijn dan dagdiensten. Het duurde langer voordat de piloten volledig hersteld waren van een serie nachtdiensten dan van een serie dagdiensten en het was voor de piloten moeilijker om met een aangrijpende nachtdienst om te gaan dan met een aangrijpende dagdienst: een aangrijpende nachtdienst zorgde voor een sterkere afname in welzijn dan een aangrijpende dagdienst. Het enige moment waarop de dagdiensten veeleisender waren dan de nachtdiensten was tijdens de start van een serie dagdiensten: de piloten rapporteerden een lager welzijn aan het begin van een serie dagdiensten dan aan de start van een serie nachtdiensten.

DISCUSSIE

Persistente gedachten. In overeenstemming met de 'perseverative cognition hypothesis' toont dit proefschrift aan dat piekeren over een stressvolle situatie ervoor zorgt dat het fysiologisch herstel van stress langzamer verloopt én dat het langer duurt voordat men in slaap valt. Toekomstig onderzoek zou zich kunnen richten op de vraag of de inhoud van de stressgerelateerde gedachten van invloed is op het herstel van stress. Je zorgen maken over de toekomst zou wellicht tot meer spanning kunnen leiden dan het terugkijken op het verleden, omdat de toekomst onzeker is waardoor het een sterkere angstreactie oproept. Ook is het belangrijk om te onderzoeken waarom sommige werknemers meer piekeren over hun werk dan anderen.

Emoties. Dit proefschrift toonde aan dat negatieve emoties leiden tot trager fysiologisch herstel van stress. Het is mogelijk dat de studenten de negatieve emoties die werden opgeroepen door de filmscène toegeschreven aan de voorgaande stressvolle rekentaak waardoor ze bleven piekeren over deze stressvolle taak. Deze verklaring veronderstelt wel dat sterkere negatieve emoties gepaard gaan met een hogere mate van piekeren, maar dat bleek niet het geval te zijn. Het is mogelijk dat we ons niet altijd bewust zijn van de mate waarin we piekeren en dat onbewuste gedachten het tragere herstel van stress kunnen verklaren. Op dit moment bestaat er geen valide methode voor het meten van onbewuste gedachten. Deze zal eerst moeten worden ontwikkeld voordat kan worden getoetst of onbewuste gedachten van invloed zijn op herstel van stress.

In tegenstelling tot de verwachting leiden positieve emoties niet tot sneller fysiologisch herstel van stress. Een mogelijke verklaring voor deze bevinding is dat het luisteren naar favoriete muziek niet alleen positieve emoties oproept, maar ook lichamelijke processen activeert waardoor het herstel van stress wordt vertraagd. De rillingen krijgen van een mooie melodie of tot tranen toe geroerd worden door een aansprekende songtekst laat zien dat het luisteren naar muziek het lichaam kan activeren. Toekomstig onderzoek zou zich kunnen richten op de vraag of het herstel van stress kan worden bespoedigd op het moment dat een positieve emoties niet gepaard gaan met lichamelijke activiteit. Dat is geen gemakkelijke opgave. Een mogelijkheid is onderzoek naar het herstel van stress bij mensen die van nature een positieve stemming hebben.

Veeleisende ploegendiensten. De longitudinale veldstudie onder traumahelikopterpiloten toonde aan dat nachtdiensten zwaarder zijn dan dagdiensten. Het herstel duurde langer na een reeks van nachtdiensten, maar ook zorgden aangrijpende nachtdiensten voor lager welzijn aan het einde van de dienst terwijl dagdiensten dit effect niet hadden. Dit resultaat veronderstelt dat emotionele werkeisen de negatieve effecten van nachtdiensten kunnen versterken. Toekomstig onderzoek zou zich kunnen richten op de vraag of emotionele steun het negatieve effect van een aangrijpende nachtdienst kan verminderen.

Sterke punten en beperkingen

Dit proefschrift onderscheidt zich door het gebruik van sterke onderzoeksmethoden. Veel stressonderzoek heeft zich met name gericht op de persoonlijke beleving van stress waardoor de lichamelijke effecten onderbelicht bleven. Ook zijn de mogelijke oorzaken en uitkomsten van stress veelal op hetzelfde moment gemeten waardoor er geen onderscheid kan worden gemaakt tussen oorzaken en gevolgen van stress. De onderzoeken beschreven in dit proefschrift includeerden zowel fysiologische maten van stress als de persoonlijke beleving, waarbij oorzaken en gevolgen van stress op verschillende tijdsmomenten zijn gemeten. Hierdoor is een betrouwbaar, valide en compleet beeld ontstaan van de factoren die het herstel van stress beïnvloeden.

Ondanks de sterke punten van dit proefschrift zijn er toch enkele noemenswaardige zwakke punten. De deelnemers aan de verschillende onderzoeken waren allemaal hoogopgeleid. Hierdoor is een terechte vraag of de resultaten ook van toepassing zijn op lager opgeleiden. Bovendien waren de werkomstandigheden van de traumahelikopterpiloten zeer specifiek waardoor ook hier de vraag kan worden gesteld of de resultaten van toepassing zijn op werkenden in andere werkomstandigheden. Daarnaast is er in het onderzoek gebruik gemaakt van één-item metingen welke niet zijn gevalideerd. Een laatste beperking is de mogelijkheid van omgekeerde causaliteit. In *Hoofdstuk 4* is bijvoorbeeld het effect van werkstress op slaapkwaliteit onderzocht, maar niet de invloed van slaapkwaliteit op werkstress. Het is aannemelijk dat een slechte nachtrust er ook voor zorgt dat je de volgende dag sneller gestrest raakt.

Praktische implicaties

Het voorkomen van stress is beter dan genezen. Wanneer werknemers invloed kunnen uitoefenen op hun werkzaamheden ervaren ze minder stress, presteren ze beter en zijn ze gezonder. Daarom is het belangrijk dat werkgevers banen creëren waarbij werknemers invloed kunnen uitoefenen op hun werkzaamheden. Toch kan niet altijd worden voorkomen dat er werkstress wordt ervaren. Soms zijn stressoren inherent aan het werk, zoals bijvoorbeeld de onvoorspelbare werkdruk bij traumahelikopterpiloten. De volgende tips kunnen je helpen om het herstel van stress te bespoedigen. Ten eerste is het belangrijk dat situaties worden vermeden die negatieve emoties oproepen en dat je zo min mogelijk piekert over het werk. Dat is makkelijker gezegd dan gedaan, maar het zoeken van positieve afleiding kan behulpzaam zijn. Het is belangrijk om te beseffen dat piekeren op geen enkele manier bijdraagt aan het oplossen van problemen. Ook is het makkelijker om thuis niet over het werk te piekeren wanneer werk en privé gescheiden worden gehouden. Een meer actieve benadering is het beoefenen van mindfulness of sporten. Beiden verbeteren de stemming en zorgen ervoor dat de aandacht wordt afgeleid van piekergedachten, waarbij sporten er ook voor zorgt dat het lichaam minder sterk reageert in stressvolle situaties.

Voor traumahelikopterpiloten is het belangrijk dat de reeks nachtdiensten maximaal uit drie diensten blijft bestaan en dat de hersteltijd niet wordt verkort. Een langere serie van nachtdiensten zal leiden tot een langere benodigde hersteltijd wat de gezondheid negatief kan beïnvloeden. Omdat de start van een serie dagdiensten relatief veeleisend was, kan worden aangeraden om de start van de dagdiensten naar een later tijdstip te verplaatsen. Hierbij moet worden beseft dat het uitstellen van de start van de dagdiensten ook zal leiden tot een later tijdstip waarop de nachtdienst eindigt. Om deze reden kan worden aangeraden om de dagdiensten iets later te laten beginnen, maar niet veel. Bijvoorbeeld om zeven uur ’s ochtends in plaats van half zeven ’s ochtends.

Conclusie

Dit proefschrift heeft een substantiële bijdrage geleverd aan de kennis over het herstel van stress. Door gebruik te maken van sterke onderzoeksmethoden kon worden aangetoond dat het piekeren over stressvolle situaties ervoor zorgt dat het langer duurt voordat het lichaam herstelt én dat het langer duurt voordat men in slaap valt. Positieve emoties zijn prettig, maar zorgen er niet voor dat het lichamelijk herstel van stress sneller verloopt. Daarentegen zorgen negatieve emoties er wel voor dat het lichamelijk herstel van stress wordt vertraagd. Tot slot toont dit proefschrift aan dat aangrijpende nachtdiensten een grotere tol eisen van het welzijn van de traumahelikopterpiloten dan aangrijpende dagdiensten en dat nachtdiensten een langere hersteltijd behoeven.

DI

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ABOUT THE AUTHOR

Mirjam Radstaak was born on August 5th 1983 in De Heurne, The Netherlands. In 2000, she finished her secondary education at Schaersvoorde in Aalten. She started studying social work but after a year she decided to switch to study psychology. She specialised in clinical psychology and she obtained her master degree in clinical psychology in 2005. Because Mirjam realised that she wanted to know more about the positive side of life, she decided to study social psychology at the Radboud University Nijmegen. Mirjam enrolled in the Behavioural Science Research Master program and wrote her master thesis about self-compassion. She obtained her research master degree in 2008 and started working as a PhD student at the department of Work and Organizational psychology at the Radboud University Nijmegen. Her PhD project was made possible by a NWO-grant provided to prof. dr. Sabine Geurts and colleagues. In 2014 Mirjam worked as a lecturer at the University of Utrecht and as a researcher at the HAN University of Applied Sciences. She currently holds a position as Assistant Professor at the department of Psychology, Health and Technology at the University of Twente.

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